U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-301 222

Water Treatment Process Modifications for Trihalomethane Control and Organic Substances in the Ohio River

Ohio River Valley Water Sanitation Commission, Cincinnati

Prepared for

Environmental Protection Agency, Washington, DC

Aug 79

PB 301222

WATER TREATMENT PROCESS MODIFICATIONS FOR TRIHALOMETHANE CONTROL AND ORGANIC SUBSTANCES IN THE OHIO RIVER

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

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SANITATION COMMISSION**

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cooperation with*

- Beaver Falls Authority
- Cincinnati Water Works
- Evansville Water Works
- Fox Chapel Authority
- Huntington Water Corporation
- Louisville Water Company
- Municipal Authority of the Borough of West View
- Pittsburgh Department of Water
- Western Pennsylvania Water Company
- Wheeling Water Department
- Wilkinsburg-Penn Joint Water Authority

and U. S. Environmental Protection Agency

Guidance in the startup phase of the project was provided by the *Steering Committee:*

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The Commission's *Water Users Committee* provided essential support, expertise, and commitment from the project's planning stages through its realization:

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Clifford Angelo, U. S. Geological Survey
Albert Campbell, Wheeling Water Treatment Plant
Lloyd N. Clausing, Portsmouth Water Treatment Plant
Don Close, Cincinnati River Forecast Center
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Victor Fender, Covington Water Works
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50272-101

REPORT DOCUMENTATION PAGE

1. REPORT NO.
ORS/WT-79/01

2.

3. Recipient's Accession No.
PB301222

4. Title and Subtitle
Water Treatment Process Modifications for Trihalomethane Control and Organic Substances in the Ohio River

5. Report Date
August, 1979

6.

7. Author(s)

8. Performing Organization Rept. No.
ORS/WT-79/01

9. Performing Organization Name and Address
Ohio River Valley Water Sanitation Commission
414 Walnut Street, Suite 900
Cincinnati, OH 45202

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C)
(G) USEPA #R-804615

12. Sponsoring Organization Name and Address
See attached

13. Type of Report & Period Covered
Final
October, 1976-August, 1979

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

Plant-scale studies at seven water utilities using the Ohio, Allegheny, Beaver, and Monongahela Rivers as their source of supply evaluated various water treatment process modifications for both the control of trihalomethane levels and the modifications' impact on bacteriological quality of the finished water. Process modifications studied, based on comprehensive organic analysis, included relocation of the chlorine application point, chlorination/ammoniation, partial or complete substitution of chlorine dioxide for chlorine, and placement of four different types of virgin granular activated carbons in filter beds. Supplemental studies included organic analysis of monthly raw and finished water samples collected for a one-year period at each of 11 participating water utilities. In addition to providing plant facilities and personnel, the 11 utilities joined USEPA in funding this project, which was conducted by the Ohio River Valley Water Sanitation Commission.

17. Document Analysis a. Descriptors
Water Treatment: Chemical Removal
Water Quality
Organic Compounds
Quality Control

b. Identifiers/Open-Ended Terms
Trihalomethane Control

c. COSATI Field/Group 13B, 7C, 14D

18. Availability Statement
Release Unlimited

19. Security Class (This Report)
UNCLASSIFIED

20. Security Class (This Page)
UNCLASSIFIED

21. No. of Pages
305

22. Price
PC A14 / MF A01

(See ANSI-Z39.18)

See Instructions on Reverse

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

WATER TREATMENT PROCESS MODIFICATIONS
FOR TRIHALOMETHANE CONTROL
AND ORGANIC SUBSTANCES IN THE OHIO RIVER

August, 1979

Ohio River Valley Water Sanitation Commission
414 Walnut Street Cincinnati, Ohio

ABSTRACT

Plant-scale studies at seven water utilities using the Ohio, Allegheny, Beaver, and Monongahela Rivers as their source of supply evaluated various water treatment process modifications for both the control of trihalomethane levels and the modifications' impact on bacteriological quality of the finished water. Process modifications studied, based on comprehensive organic analysis, included relocation of the chlorine application point, chlorination/ammoniation, partial or complete substitution of chlorine dioxide for chlorine, and placement of four different types of virgin granular activated carbons in filter beds. Supplemental studies included organic analysis of monthly raw and finished water samples collected for a one-year period at each of 11 participating water utilities. In addition to providing plant facilities and personnel, the 11 utilities joined USEPA in funding this project, which was conducted by the Ohio River Valley Water Sanitation Commission.

This report was prepared in fulfillment of USEPA Grant R-804615 for project activities for the period October 1976 to August 1979.

DISCLAIMER

Mention of trade names, commercial products or other identifications does not constitute endorsement or recommendation.

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ACKNOWLEDGMENTS

The Commission is especially appreciative of the efforts of the superintendents, directors and managers of the participating water utilities, who assisted in development, financing and conduct of the project. Special thanks is accorded the water utility personnel, who devoted many hours to the operation of the project.

- Fox Chapel Authority
  - Melvin Hook; Reginald Adams and Thomas Stehle (Reginald Adams Laboratory, Pittsburgh, Pennsylvania)
- Wilkinsburg-Penn Joint Water Authority
  - Harold McFarland, Dennis Beck
- Pittsburgh Department of Water
  - John Miller, John Beck and staff
- Western Pennsylvania Water Company
  - William Neuman, Michael Burns and staff
- West View Water Authority
  - Joseph Dinkel
- Beaver Falls Authority
  - Frank Richter and staff
- Wheeling Water Department
  - Albert Campbell and staff
- Huntington Water Corporation
  - Thomas Holbrook and staff
- Cincinnati Water Works
  - Richard Miller, Edward Kispert and staff
- Louisville Water Company
  - Frank Campbell, Don Duke and staff
- Evansville Water Works
  - Mahlon Henderson and Matthew Rexing

The cooperation of Radian Corporation of Austin, Texas, contributed to the success of the project. Individuals who merit special acknowledgment are Dr. Donald Rosebrook and Dr. Lawrence Keith; Dr. Kenneth Lee, David Present and the gas chromatography staff; and Dr. Robert Spraggins and the mass spectrometry staff.

The comprehensive task of preparing the initial draft report was carried out by Richard J. Miltner, Principal Investigator, and Bonnie Barger Cummins, Project Scientist, under the general direction of the Project Director, Robert J. Boes.

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October 11, 1979

SECTION 1

INTRODUCTION

BACKGROUND

In 1974 and 1975, surveys and studies reported the identification of trihalomethanes and other organic compounds in the public drinking water supplies in the Ohio River Valley and nationwide.[1-3] Some compounds were present in rivers that were the water sources for water utilities, and trihalomethanes and other compounds were formed during the water treatment process.

Because of increasing concern about these organic compounds, the Ohio River Valley Water Sanitation Commission (ORSANCO) and its Water Users Committee, representatives of public and industrial water supply systems using the Ohio River and major tributaries as their source, developed a cooperative project to evaluate treatment process modifications for the control of trihalomethanes and analyze the utilities' raw and finished waters for organic substances. The project established a program to be operated by the Commission with the assistance of eleven water utilities, who pledged both financial support and use of their water treatment facilities and personnel. The U. S. Environmental Protection Agency (USEPA) awarded the Commission a research grant for the project in October 1976.

PARTICIPATING UTILITIES

The project utilities (Figure 1) were:

Evansville Water Department, Indiana
Louisville Water Company, Kentucky
Cincinnati Water Works, Ohio
Huntington Water Corporation, West Virginia
Wheeling Water Department, West Virginia
Beaver Falls Authority, Pennsylvania
Municipal Authority of the Borough of West View, Pennsylvania
Western Pennsylvania Water Company, Pennsylvania
Pittsburgh Department of Water, Pennsylvania
Wilkinsburg-Penn Joint Water Authority, Pennsylvania
Fox Chapel Authority, Pennsylvania

OBJECTIVES

The first of two major objectives was the investigation and evaluation of modifications of water treatment practices for the control of trihalomethanes.

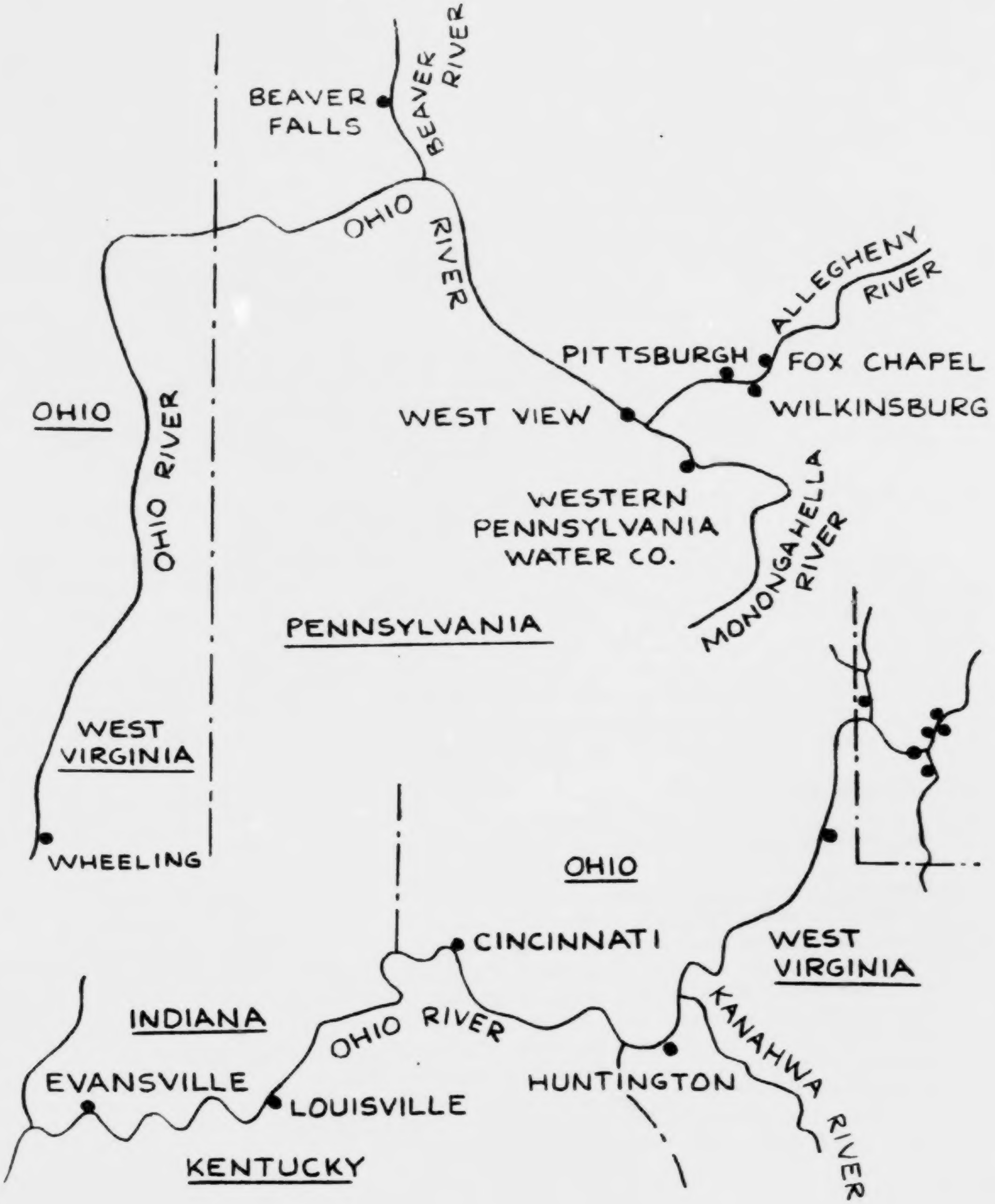


Figure 1. Utility locations.

These control studies were based on bench scale and pilot plant studies done by USEPA to investigate, sample for and control trihalomethanes.[4-7] This objective also included an investigation of bacteriological levels to ensure that treatment modifications designed to lower trihalomethane concentrations were not compromising finished water quality.

The second major objective was the determination of the levels of trihalomethanes and other selected organic compounds in raw and finished waters at all project utilities for one year. Other compounds for investigation were selected from a list designated by USEPA as organic Priority Pollutants for which an analytical protocol was available.[8]

CONTRACT LABORATORY

A laboratory service contract was awarded to the Radian Corporation, Austin, Texas, after a review of proposals from several private laboratories detailing analytical costs and capabilities for performing gas chromatography (GC) and gas chromatography/mass spectrometry (GC/MS) analyses for selected organic Priority Pollutants.

SCOPE OF WORK

Early in the project, members of the staff visited each participating water utility to study its treatment practices and to determine the level of participation by each utility. Minimum participation included monthly sampling for organic analyses of raw and finished waters for one year, and measurement and reporting of several background water quality parameters. Participation in trihalomethane control studies included: sampling of raw, in-plant, and finished waters for organic analysis several times a week for periods ranging from four weeks to several months; determination of levels of routine physical, chemical, and bacteriological water quality parameters for each sampling location; and reporting of hydraulic, maintenance, and operation data during routine and modified treatment (Sections 5 and 6).

Monthly sampling began at all 11 utilities in July 1977 and continued through June 1978. Trihalomethane control studies at seven of the utilities began in July 1977 and concluded in November 1978. The project staff worked with each utility to coordinate sampling schedules and shipment to the contract laboratory and to follow the progress at those utilities involved in trihalomethane control studies.

The staff worked with Radian Corporation personnel to develop GC and GC/MS quality control programs, coordinate organic analyses and shipment of sample bottles to the utilities, and review the progress of organic analyses. This review led to changes in some analytical procedures and the implementation of a more rigorous quality assurance program. (Laboratory procedures and quality assurance programs are described in Section 5 and Appendices A, B, D, G and I.)

The project staff reviewed, interpreted and compiled all organic data received from the contract laboratory and all data received from the utility laboratories (Sections 6 and 7). Utility personnel collected a total of 3,446 samples for organic analyses of which 2,950 produced usable chromatograms or mass spectra. Data from about 500 samples were not available because of damage in shipment, damage at the contract laboratory, headspace development in volatile samples, samples not analyzed, and data not usable for reasons including occasional loss of GC sensitivity or deviation from routine GC operating conditions.

SECTION 2

CONCLUSIONS

The following conclusions are based on findings summarized in this section. They apply to raw and finished water in the treatment plant but not to the water in the distribution system.

1. Trihalomethanes are formed during the treatment of surface water when free chlorine is present for significant periods of time.

2. Modifications of the chlorination process which may be viable trihalomethane control methods include: relocation of the initial chlorine application to a location where treatment has reduced the precursor concentration; ammoniation to convert free to combined chlorine; and chlorine dioxide as an alternative to chlorine as the initial disinfectant.

3. Granular activated carbon (GAC) used in place of sand in the gravity filters (filtration/adsorption) may be an effective trihalomethane control process for approximately two months; however, periodic GAC reactivation is necessary if GAC is to be used for trihalomethane control for extended periods of time.

4. Evaluation of the effectiveness of treatment process modification for trihalomethane control should include determination of instantaneous and terminal trihalomethane concentrations and the trihalomethane formation potential (a measure of precursor concentration) to aid in defining changing precursor levels in the raw water and in determining the effects of treatment on precursor removal and trihalomethane formation.

5. Total coliform and standard plate count levels should be determined routinely on in-process and finished water samples to ensure that process modification for trihalomethane control has not adversely affected bacteriological levels in the treated water.

6. Process modification for trihalomethane control should extend over a period of time adequate to determine short-term, seasonal and other variations in raw water precursor concentrations, bacterial levels, and other water quality parameters, and to evaluate the effects of these variations on the quality of the treated water.

7. For the evaluation of raw, in-process, and finished water quality, a complete and continuing quality assurance program is necessary to ensure the accuracy and precision of the analytical procedures and the resulting data for trihalomethanes and other organic compounds.

8. Chloroform and other trihalomethanes were detected in many raw and all treated surface water samples. At most utilities, the reaction between precursor and free chlorine resulted in significant increases in trihalomethane concentrations. Other compounds occasionally present in raw and treated water samples included carbon tetrachloride, dichlorobenzene isomers, 1,2,4-trichlorobenzene, 1,2-dichloromethane and several polyaromatic hydrocarbons.

9. Analytical procedures more sensitive than those employed for project samples (lower detection levels generally 0.1 to 0.2 ug/L) would be necessary to evaluate the removal of organic compounds, other than trihalomethanes, by normal or modified water treatment processes.

SUMMARY OF FINDINGS

The following summarizes the results of the treatment process modification studies and the analysis of raw and finished water monthly samples.

Trihalomethanes

Chloroform was present in the majority of untreated surface water samples at levels generally less than 1 ug/L; bromodichloromethane and dibromochloromethane were present less frequently, with most levels below 0.1 ug/L; bromoform and dichloroiodomethane were not present above 0.1 ug/L.

Trihalomethanes were formed during water treatment in the presence of free chlorine. Trihalomethane levels in treated water (clear well effluent) varied seasonally, with the lowest levels occurring during the winter and the highest levels during the summer. The levels also varied with each utility's treatment. Total trihalomethane (TTHM) levels for finished surface waters ranged from 2 ug/L at one utility in February to 240 ug/L at another utility in August. Finished water total trihalomethane levels at West View, a groundwater source, did not exceed 2 ug/L. For ten utilities treating surface water, trihalomethane levels in finished waters were:

	Concentration, ug/L	
	Mean Annual	Maximum
Chloroform	35	180
Bromodichloromethane	13	54
Dibromochloromethane	5.6	33
Bromoform	0.4	4.4
Dichloroiodomethane	0.1	1.0
Total trihalomethanes	54	--

Relatively higher concentrations of brominated trihalomethanes resulted in finished water when the in-plant reaction time with free chlorine was reduced.

All finished waters contained unreacted trihalomethane precursor as measured by trihalomethane formation potential (THMFP). Data averaged from ten utilities treating surface water indicated that 23% of raw water THMFP was converted to total trihalomethane during treatment, 37% of raw water THMFP was removed by treatment, and 40% of raw water THMFP was passed into the distribution system. Reduction in terminal TTHM concentrations generally coincided with reduction in turbidity levels.

Trihalomethane Treatability

Moving the point of initial chlorine application to a location where treatment had reduced precursor levels resulted in decreased instantaneous trihalomethane concentrations in the finished water, because a better quality water, in terms of reduced THMFP, was chlorinated. The reduction of precursor-chlorine reaction time was also a factor in the decreased trihalomethane formation.

In studies at Pittsburgh and Wheeling, significant reduction in bacterial densities occurred in unchlorinated waters when potassium permanganate was fed with other chemicals prior to flocculation and settling.

At Pittsburgh, Wheeling and Cincinnati, moving the initial chlorine application point caused a delay in reduction of bacterial densities, but the bacterial quality of the finished waters was maintained.

The Louisville study showed that when sufficient ammonia was applied to in-plant waters to convert free chlorine to combined chlorine, little or no further trihalomethane formation resulted. The bacterial quality of the finished water was satisfactory; ammoniation followed three hours of free chlorine contact time. At the Western Pennsylvania Water Company's Hays Mine Plant, only very low levels of trihalomethane were formed when raw water ammonia levels were such that no free chlorine resulted from raw water chlorination.

The study at the Western Pennsylvania Water Company also showed that little or no trihalomethanes were formed when chlorine dioxide was fed to the raw water in place of chlorine. Although 1.5 mg/L chlorine dioxide was not as effective as 2.6 mg/L chlorine in reducing raw water bacteria levels, clear well chlorination provided adequate disinfection. Chlorine dioxide was generated from sodium chlorite and hydrochloric acid at an 80% yield and with only limited formation (less than 5%) of free chlorine. Although 60 to 70% of the chlorine dioxide reacted with substances in the water forming chlorite ion, flocculation, settling and filtration through two-and-one-half year old GAC reduced the residual chlorite concentration in the treated water to less than 0.1 mg/L.

The effects of individual treatment materials, including powdered activated carbon (PAC), potassium permanganate or chlorine dioxide, on precursor levels could not be determined, because all of the chemicals are generally added at a single point prior to flocculation and settling.

During summer months at Huntington and Beaver Falls, virgin granular activated carbon (GAC) operated in the filtration/adsorption mode in beds designed for sand filtration was exhausted for the removal of chloroform at seven to 15 weeks of operation, for bromodichloromethane at eight to 15 weeks of operation, for dibromochloromethane at eight to 15 weeks of operation, for total trihalomethane at seven to 15 weeks of operation, and for THMFP at seven to 12 weeks of operation. Time to exhaustion was different for each utility and type of GAC used. GAC filter/adsorbers passed carbon tetrachloride at concentrations that could not be differentiated from influent concentrations after four to seven months of operation, and 1,4-dichlorobenzene at concentrations that could not be differentiated from influent concentrations after five to 12 weeks of operation.

At Huntington and the Western Pennsylvania Water Company, GAC filter/adsorbers which had been in service for one to two-and-one-half years were exhausted for the removal of chloroform, bromodichloromethane, dibromochloromethane, and instantaneous TTHM.

Desorption from GAC filter/adsorbers was observed. GAC in use for one to two-and-one-half years at Huntington desorbed carbon tetrachloride. When GAC influent trihalomethane concentrations were significantly reduced, two-and-one-half year old GAC desorbed trihalomethanes at the Western Pennsylvania Water Company, and GACs in service for five months desorbed trihalomethanes at Beaver Falls.

In three studies (Huntington, Beaver Falls and Western Pennsylvania Water Company) bacterial densities in GAC effluent waters exceeded densities in GAC influent waters when water temperatures exceeded 10°C. The bacterial quality of the finished waters was satisfactory with clear well chlorination.

Other Organic Compounds

Carbon tetrachloride was occasionally present at concentrations from 0.1 to 0.6 ug/L in raw water at and downstream from Huntington. Carbon tetrachloride was occasionally present at 0.1 to 6 ug/L concentrations in finished surface waters at all of the utilities. Its presence in finished waters was probably attributable to contamination of chlorine used for disinfection.

Chlorobenzene was occasionally present in Huntington's raw and treated water at concentrations up to 1 ug/L. It was not found in untreated or finished waters upstream from Huntington. It was frequently found in West View's untreated groundwater at concentrations reaching 3.9 ug/L. After a reported upstream spill, chlorobenzene was found at 8.5 ug/L in a finished surface water.

During the winter months, polyaromatic hydrocarbons (PAHs)--naphthalene, acenaphthylene, acenaphthene, fluorene, fluoranthene, pyrene, and phenanthrene and/or anthracene--were present in raw and finished waters at concentrations above 0.1 ug/L. Some GAC filter/adsorbers appeared to be effective in removal of the PAHs.

Dichlorobenzene isomers were occasionally present in raw and finished waters at levels above 0.2 ug/L. They were more frequently detected at and downstream from Huntington. During a reported upstream spill, 1,4-dichlorobenzene was found in a treated surface water at a concentration of approximately 11 ug/L.

1,2,4-Trichlorobenzene was occasionally present in raw and finished waters at levels greater than 0.2 ug/L. It was more frequently found at and downstream from Cincinnati.

Unidentified halocarbons were detected in chlorinated waters but these compounds were rarely found in raw waters. These may have been chlorination products or may have resulted from contamination of chlorine used for disinfection.

1,2-Dichloroethane, 1,2-dichloropropane, and 1,1-dichloroethane were occasionally present in raw and finished waters at concentrations of 0.1 to 1 ug/L.

Tetrachloroethylene was found in Allegheny River water at approximately 60 ug/L as a result of what appeared to be an upstream spill.

Other specific organic Priority Pollutants were not present or were rarely present at or above their lower detection levels in raw and finished waters.

SECTION 3

AREAS FOR FURTHER STUDY

During the winter months, several polyaromatic hydrocarbons were identified in raw and finished waters at most project utilities. Further research into the presence and concentration of these compounds and effective treatment methods for their removal is needed.

Several Priority Pollutant halocarbons were identified at and downstream from Huntington, West Virginia. Organic analyses of Kanawha River samples collected for another project indicated that these halocarbons in the Ohio River at Huntington originated from the Kanawha River. A comprehensive point source and river survey for these and other organic compounds in the industrialized section of the Kanawha River would provide information on specific organic compounds to be considered in renewal of NPDES permits.

Carbon tetrachloride and unidentified halocarbons may have been introduced to treated waters as a result of chlorine contamination. Chlorine manufacturing processes should be investigated and procedures for control of contamination by carbon tetrachloride and possibly by other halocarbons should be considered.

Unidentified halocarbons were found in chlorinated waters that were rarely found in raw waters and may be chlorination products. Continuing research to identify chlorination products other than trihalomethanes is needed.

When water temperatures exceeded 10°C, bacterial densities in GAC filter effluents were higher than in GAC influents at three utilities using GAC for filtration/adsorption. Comprehensive studies of the nature of this increase in bacterial densities and the development of methods to control bacterial levels in GAC effluent are suggested.

Project utilities typically feed powdered activated carbon and potassium permanganate during treatment. This project was not able to evaluate the full-scale effects of these chemicals on trihalomethane control but their effects at typical feed rates should be studied.

This project was not able to evaluate the full-scale effect of applied chlorine dioxide on precursor levels. Further study of the effect of reasonable feed rates of chlorine dioxide on the resulting chlorine species and the nature of resulting organic compounds is needed.

SECTION 4

PROJECT ORGANIC COMPOUNDS

TRIHALOMETHANES

Five individual trihalomethane (THM) compounds were qualified and quantified in utility waters. They were chloroform, bromodichloromethane, dibromochloromethane, bromoform and dichloroiodomethane. In order to facilitate the investigation of trihalomethanes and their control, other parameters were also utilized. Although these parameters are discussed elsewhere[7] they will be defined here as they applied to this project.

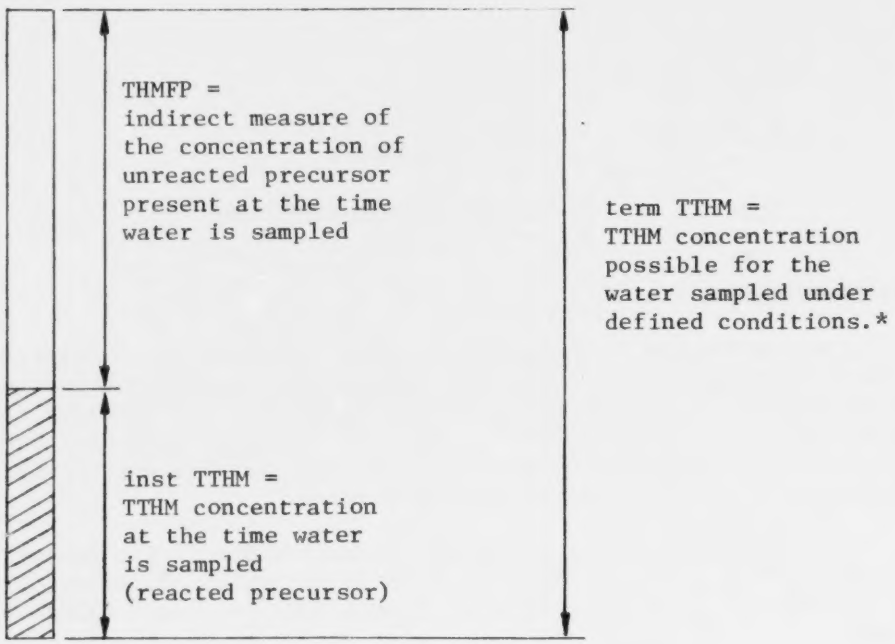
1. Total trihalomethane (TTHM) concentration is the summation of the concentrations of five individual THMs in a sample. Example: 42 ug/L $CHCl_3$ + 12 ug/L $CHBrCl_2$ + 8 ug/L $CHBr_2Cl$ + 1 ug/L $CHBr_3$ + 1 ug/L $CHICl_2$ = 64 ug/L TTHM.

2. Instantaneous TTHM (inst TTHM) is the concentration of TTHM in the water at the time the sample is collected.

3. Terminal TTHM (term TTHM) is the sum of TTHM present in the water at the moment of sampling and TTHM subsequently formed during additional reaction time under defined conditions. During the project, the reaction was driven toward completion by adding chlorine to exhaust the precursor. The sample was stored at finished water pH and temperature for seven days, i.e., beyond the normal detention time in the distribution system of the utilities, with sufficient free chlorine added to satisfy demand. After seven days under storage conditions, a concentration was reached that was assumed to represent a completed reaction. For the project, that concentration was defined as terminal TTHM.

4. Trihalomethane formation potential (THMFP) is the difference between the terminal TTHM and the instantaneous TTHM (term TTHM - inst TTHM = THMFP), an indirect measure of the unreacted precursor in the water sampled. It is the increase in the TTHM concentration that occurred during the storage period for the determination of the terminal TTHM concentration. The unreacted precursor has the potential to further increase TTHM concentrations in the presence of free chlorine.

These parameters, illustrated in Figure 2, were used to evaluate trihalomethane concentration and control in Sections 6 and 7.



*buffered to finished water pH, 15 mg/L chlorine added, stored for seven days at finished water temperature.

Figure 2. Graphical representation of trihalomethane parameters.

OTHER PRIORITY POLLUTANTS

Analyses for numerous other organic compounds were performed throughout the study. These compounds were chosen from USEPA's Priority Pollutants list[8] on the basis of three criteria: they were of known or suspected health concern; their occurrence in the waters of the Ohio Valley was a possibility because of their association with industrial discharges or agricultural runoff; and USEPA had proposed a GC/MS analytical procedure for analyses for these compounds in water.[8]

Consideration of project objectives, available funds, and analytical costs and capabilities led to a decision to analyze for some, but not all, of the Priority Pollutants. Tables 1, 2 and 3 list the organic compounds for which analyses were performed.

Analyses were not performed for three groups of organic compounds: volatile hydrocarbons by GC/flame ionization detection (toluene, benzene and ethyl benzene), because of unacceptable detection levels; acid extractable halocarbons by GC/Hall detection (chlorophenols), because of unacceptable detection levels; and base/neutral extractable nitrocarbons (benzidine, nitrotoluenes, etc.), because of detection levels and GC/MS sensitivity (Section 5 and Appendix H).

TABLE 1. PROJECT ORGANIC COMPOUNDS
PURGEABLE HALOCARBONS, GC/HALL DETECTOR

Chloroform
Bromodichloromethane
Dibromochloromethane
Bromoform
Dichloroiodomethane
1,1-Dichloroethane
1,2-Dichloroethane
1,1,1-Trichloroethane
Carbon Tetrachloride
1,2-Dichloropropane
trans-1,3-Dichloropropene
Trichloroethylene
cis-1,3-Dichloropropene
1,1,2-Trichloroethane
1,1,2,2-Tetrachloroethane
Tetrachloroethylene
Chlorobenzene

TABLE 2. PROJECT ORGANIC COMPOUNDS
BASE-NEUTRAL EXTRACTABLE HALOCARBONS, GC/HALL DETECTOR

1,3-Dichlorobenzene
1,4-Dichlorobenzene
Hexachloroethane
1,2-Dichlorobenzene
bis(2-Chloroiosopropyl) ether
bis(2-Chloroethyl) ether
1,2,4-Trichlorobenzene
Hexachlorobutadiene
bis(2-Chloroethoxy) methane
Hexachlorocyclopentadiene
2-Chloronaphthalene
4-Chlorophenyl phenyl ether
4-Bromophenyl phenyl ether
α-BHC
-BHC (Lindane)
-BHC
Heptachlor
β-BHC
Aldrin
Heptachlor epoxide
α-Endosulfan
Dieldrin
DDE
Endrin
DDD
β-Endosulfan
DDT
Methoxychlor

TABLE 3. PROJECT ORGANIC COMPOUNDS
BASE-NEUTRAL EXTRACTABLE HYDROCARBONS, GC/FLAME IONIZATION DETECTOR

Naphthalene
Acenaphthylene
Acenaphthene
Dimethyl phthalate
Fluorene
Diethyl phthalate
Phenanthrene
Anthracene
Di-n-butyl phthalate
Fluoranthene
Pyrene
Butyl benzyl phthalate
bis(2-Ethylhexyl) phthalate
1,2-Benzanthracene
Chrysene
3,4-Benzofluoranthene
11,12-Benzofluoranthene
Benzo(a)pyrene
Indeno(1,2:C,D)pyrene
1,2:5,6-Dibenzanthracene
1,12-Benzoperylene

GAS CHROMATOGRAPHY VERSUS MASS SPECTROMETRY

The USEPA protocol for the organic Priority Pollutants is based on GC/MS analysis.[8] A decision was made to analyze all samples by GC and the Hall or other detectors to provide presumptive identification of organic compounds, because the cost of GC/MS procedures would limit the number of samples which could be analyzed. GC/MS analyses were used to provide positive or negative confirmation of presumptive identifications. For individual organic compounds there were significant differences between the lower detection levels by GC/detector and GC/MS. Specific examples are discussed in Section 7.

SECTION 5

ANALYTICAL PROCEDURES AND QUALITY ASSURANCE

ORGANIC CONTRACT LABORATORY

At submicrogram and microgram per liter (ug/L) levels of analysis for organic compounds, a comprehensive quality assurance program must accompany all aspects of sample handling and analysis. The program is necessary for two reasons: GC reports of an organic compound should be the result of the presence of the compound in the water at the time it was sampled and not the result of procedural contamination; and, the significance (accuracy and precision) of the data must be known before interpretation. The following subsections and their related appendices describe the quality assurance program.

General Laboratory Controls

Extensive laboratory control procedures were necessary to ensure that interferences were definable at acceptably low concentrations. General laboratory control procedures involved the following: the cleaning, preparation and handling of bottles for sample collection and of laboratory glassware used in the analysis of project samples; the preparation of low organic water for purgeable blank analyses, preparation of purgeable standards, rinsing of glassware, recovery tests for extractable compounds, and preparation of buffers; the identification and control of interferences from materials such as solvents and gases for purging and chromatography; and the storage of project samples to maintain integrity prior to analysis. These control procedures are detailed in Appendix A.

The effectiveness of these controls was routinely evaluated by the laboratory. At the same time project samples were analyzed, system blanks were analyzed to detect interferences. When an unacceptable interference was observed in system blanks, sample analyses were discontinued until the interference was identified and/or controlled.

Analytical Procedure for Purgeable Halocarbons

The purgeable halocarbon Priority Pollutants for which routine analysis was performed and the approximate lower detection levels are listed in Table 4.

The USEPA Priority Pollutant Protocol[8] for analysis of halocarbons by purge, trap, desorption and gas chromatography/mass spectrometry (GC/MS) was revised by the laboratory[9] to enable analysis by purge, trap, desorption and

TABLE 4. PURGEABLE HALOCARBONS, GC/HALL DETECTOR

Compound	Approximate Lower Detection Level ug/L
1,1-Dichloroethane	0.1
Chloroform	0.1
1,2-Dichloroethane	0.1
1,1,1-Trichloroethane	0.6 - 2.6[a]
Carbon Tetrachloride	0.1
Bromodichloromethane	0.1
1,2-Dichloropropane	0.1
trans-1,3-Dichloropropene	0.1
Trichloroethylene	0.5 - 1.9[a]
cis-1,3-Dichloropropene	
1,1,2-Trichloroethane	0.1
Dibromochloromethane	
Dichloroiodomethane	0.1[b]
Bromoform	0.1
1,1,2,2-Tetrachloroethane Tetrachloroethylene	1.0 - 3.4[a]
Chlorobenzene	0.1

[a] Laboratory contamination; see Section 7

[b] Quantification relative to 1,4-dichlorobutane

GC/Hall detection with occasional GC/MS verification. A detailed description of the purge, trap, desorption and GC/Hall detector equipment and analytical procedures as used by the laboratory is given in Appendix B.

Qualitative and quantitative determinations of the purgeable halocarbons were based on a calibration standard of these compounds (excluding dichloroiodomethane) and an internal standard of 1,4-dichlorobutane added to calibration standards and project samples. These determinations were automatically performed by a Hewlett Packard 3380A programmable integrator[10] and were reviewed in each chromatogram by the project staff. Qualification (identification) of peaks in sample chromatograms was based on relative retention time (RRT) matching within ± 5% of RRT of standard peaks in calibration chromatograms. Quantification was based on a comparison of the response of a compound and the internal standard in the calibration. Figure 3 represents a typical chromatogram of a calibration standard, Figure 4, a typical system blank chromatogram and Figure 5, a typical chromatogram of a project sample.

A stable calibration standard of dichloroiodomethane could not be maintained. Therefore, its relative retention time was obtained only once and it was not a component of the purgeable halocarbon standard. Qualification in field samples was based on this relative retention time. The GC/MS laboratory confirmed dichloroiodomethane GC identified in this manner. Routine quantification was relative to 1,4-dichlorobutane.

Both qualitative and quantitative data produced by GC/Hall analyses are presumptive. However, validity of the GC/Hall procedure for purgeable com-

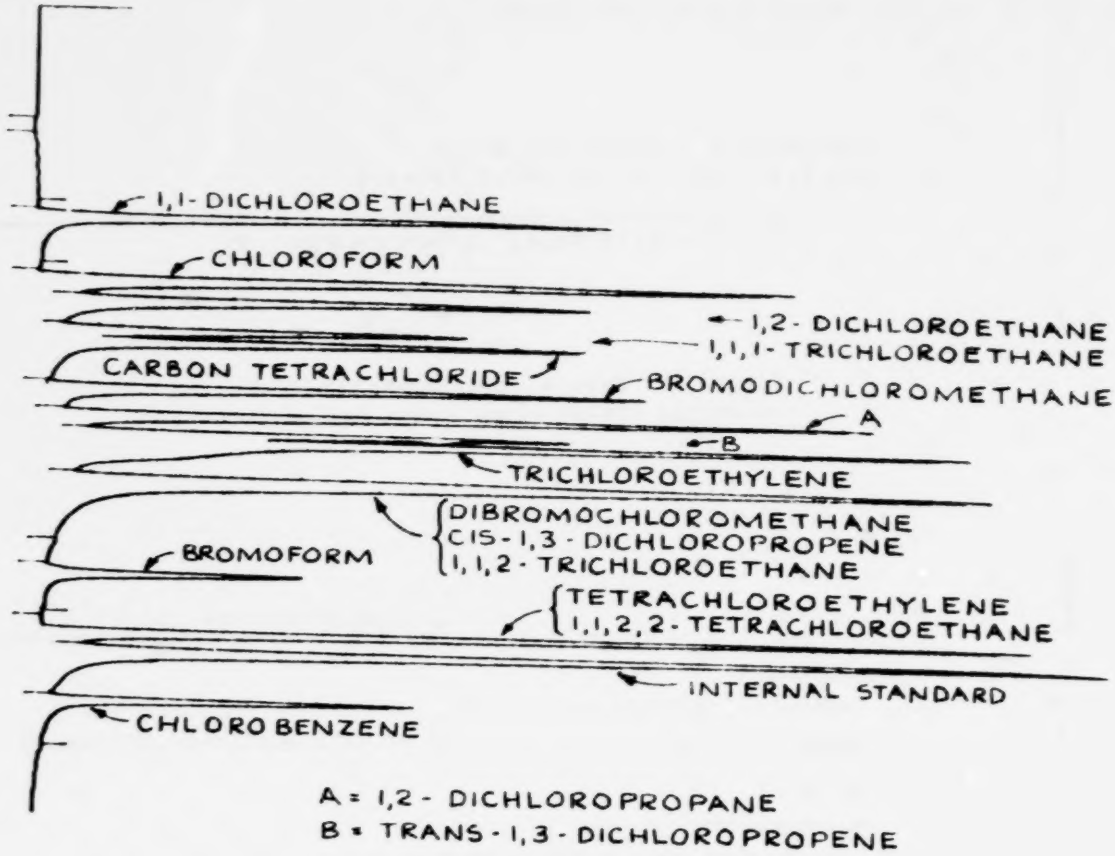


Figure 3. Typical gas chromatogram of purgeable halocarbon Priority Pollutants calibration standard using Hall detector.

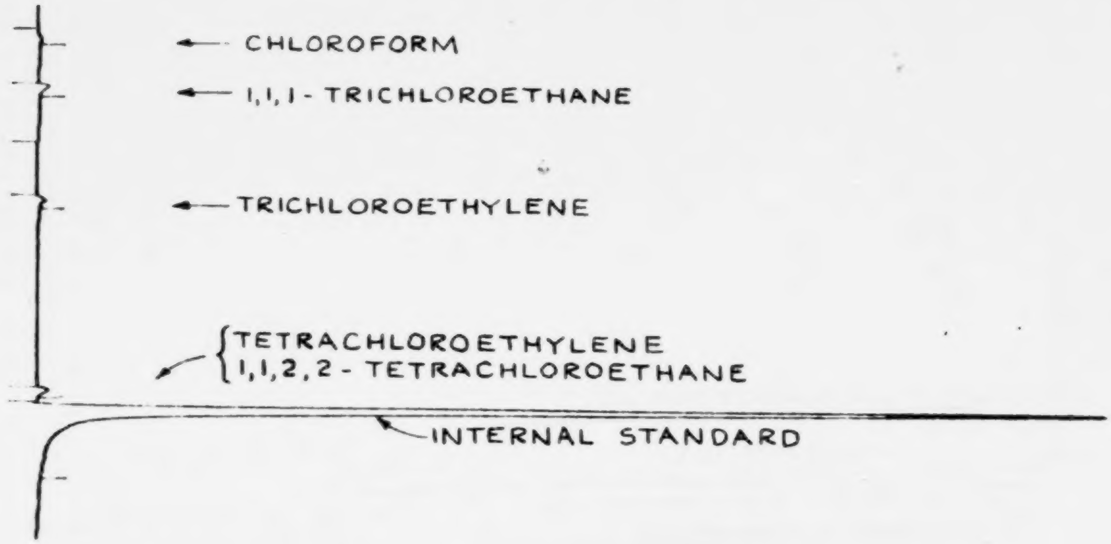


Figure 4. Typical gas chromatogram of purgeable system blank using Hall detector.

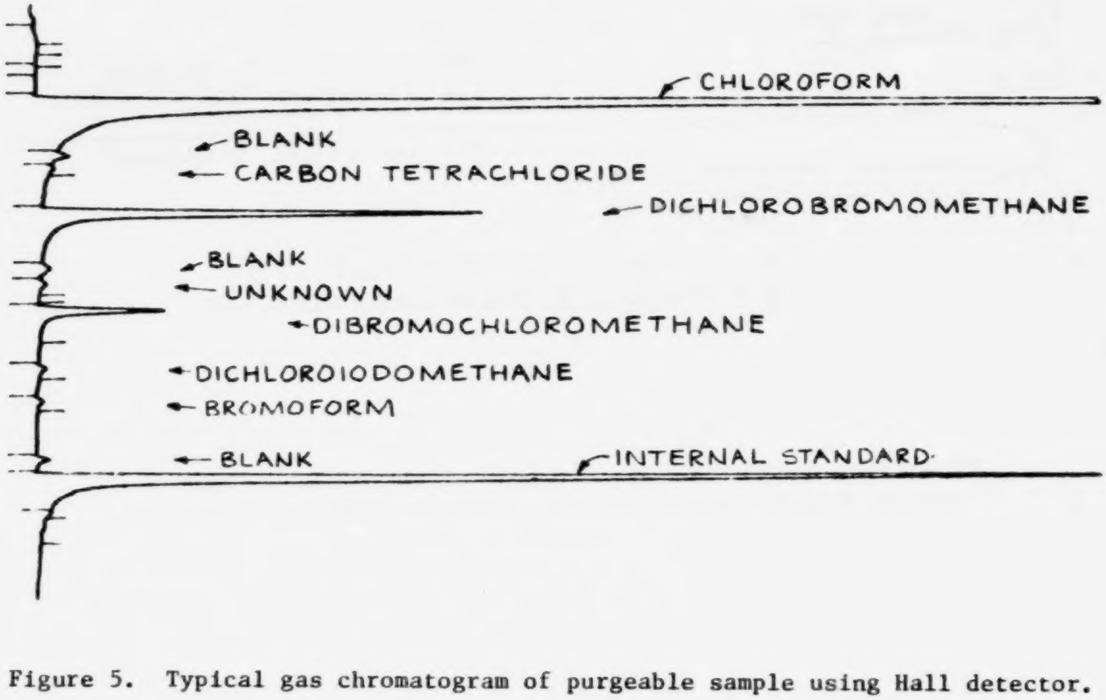


Figure 5. Typical gas chromatogram of purgeable sample using Hall detector.

pounds was maintained through the use of daily calibration standards, USEPA reference standards, an internal standard for qualification and quantification and occasional GC/MS verification.

The trihalomethane compounds in terminal level samples were also evaluated by purge, trap, desorption and GC/Hall detection. The calibration standard contained only chloroform, bromodichloromethane, dibromochloromethane, bromoform, and the internal standard, 1,4-dichlorobutane. The equipment and analytical procedures used were the same as for other purgeable halocarbons, with the exception of temperature programming. Details are given in Appendix B.

Quality Assurance for Purgeable Halocarbons

In order to ensure that GC reports of a compound were not a result of interference and to provide sufficient data to define the accuracy and precision of GC data, laboratory analyses were supplemented by a comprehensive quality assurance program.

Periodic Quality Assurance--

The laboratory established a concentration above which the purgeable halocarbons could be routinely detected in project samples by the method of analysis detailed in Appendix B. The lower detection level was defined as an integrable peak greater than an arbitrary area count of 1000 units and was determined by diluting the calibration standards by factors of two until integration could not occur. These levels are listed in Table 4. For most of the purgeable halocarbons, the approximate lower detection level was 0.1 ug/L. This level appeared to have good validity when compared to GC/MS verification of GC/Hall detector data close to the reported detection level and when tested by periodic analyses of calibration standards at 0.1 ug/L.

Because the HP 3380A integrator assumes linearity of the Hall detector response when quantifying, the linear relationship between the amount of compound purged and the Hall detector response was tested. A least squares regression analysis, assuming a linear model, was done using detector response as the dependent variable. Concentrations expected in project samples were evaluated, i.e., chloroform ranging from 1.0 ug/L to 200 ug/L, bromoform ranging from 1.0 ug/L to 10 ug/L. Correlation coefficients of 0.98 verified the linearity of the Hall detector over the range of concentrations in project samples.

The variability of standard analyses at several concentrations was evaluated periodically. Appendix C, Tables C-1 to C-15, contains compiled data on the reproducibility of laboratory standards by purge, trap, desorption and Hall-detection over a range of concentrations. The data indicate that concentrations were significant to two figures from 0.1 ug/L to 200 ug/L. This level of significance was applied to project sample data.

Routine Quality Assurance--

Daily control criteria and limits were established by the project and laboratory staffs. If control limits were exceeded, sample analyses were discontinued until conditions were again within the limits. Control criteria data were also accumulated for determination of the significance of project sample data.

The daily control program involved an initial analysis of a 16-component calibration standard containing the 1,4-dichlorobutane internal standard. This analysis was used to program the integrator for relative retention times and response factors. Interspersed with subsequent project sample analyses were the following: USEPA reference sample analyzed daily as an unknown against the calibration standard; low organic water analyzed periodically through the day as a system blank to determine possible interference from the syringe, purge, trap, desorption, GC/Hall system or laboratory air; each day, a previously analyzed sample was reanalyzed for comparative evaluations of day-to-day analytical conditions; and calibration standard analyzed approximately every six hours as an unknown to determine stability of the system for RRT and response factors. In addition to the laboratory control program, approximately 12 per cent of project field samples were submitted in replicate.

The background concentrations defined by system blanks were used to correct data by one of two methods. An interference detected on only one analytical day was subtracted from all sample data produced that day. A recurring interference was evaluated over the period of occurrence and statistically weighted (mean interference plus two standard deviations) to reflect the interference over that period. This statistical correction was subtracted from all sample data produced over that period.

Application of Quality Assurance Data for Purgeable Halocarbons to Sample Data--

Accumulated quality assurance data from analyses of USEPA reference samples, calibration standards handled as unknowns, replicate field samples, and reanalysis of single field samples are presented in Appendix C for the purgeable halocarbons. These data defined the significance of the sample data. The following examples demonstrate the application of these quality assurance data to sample data.

Quality assurance data for chloroform are presented in Appendix C, Table C-1 and Figures C-1 to C-3. An examination of these data provides a measure of both the accuracy and precision that must be considered in interpretation of chloroform data. Data were compiled from analyses of replicate field sets and from replicate analyses of single field samples. The mean concentration of each data set was plotted versus the deviation of the set about the mean. (For example, a pair of field duplicates were analyzed for instantaneous chloroform. Concentrations obtained for the pair were 88 ug/L and 72 ug/L producing a mean value of 80 ug/L and a relative average deviation of ± 10%. For this set, the mean of 80 ug/L was plotted versus the relative average deviation of ± 10%. If more than two field replicates were analyzed for instantaneous chloroform and concentrations were 41 ug/L, 45 ug/L and 46 ug/L, a mean value of 44 ug/L and a relative standard deviation of ± 6%, the mean of 44 ug/L was plotted versus the relative standard deviation of ± 6%.)

Instantaneous chloroform data obtained from the replicate sets were plotted in concentration ranges. See Figure C-1. In the concentration range of 5.0 to 140 ug/L, chloroform replicated within 19% within a set, 95% of the time. Thus, if the concentration of chloroform in a sample was determined to be 42 ug/L, reanalysis of the sample or analysis of a duplicate field sample produced a concentration within ± 19% of 42 ug/L, 95% of the time. Therefore, concentrations of 36 ug/L and 47 ug/L could not be differentiated.

For instantaneous chloroform data in the concentration range of 1.0 to 5.0 ug/L, chloroform replicated within 23% within a set, 95% of the time, as shown in Figure C-2. As the concentrations of instantaneous chloroform decreased below 1.0 ug/L and approached the approximate detection limit of 0.1 ug/L, variability increased greatly. Figure C-2 shows that the variability approached ± 100% at the detection limit. Therefore, concentrations of 0.1 ug/L and 0.2 ug/L could not be differentiated.

Terminal chloroform data were also plotted for sets of field samples and are shown in Figure C-3. In the concentration range of 5.0 to 325 ug/L, chloroform replicated within 20% within a set, 95% of the time, not unlike the ± 19% variability for instantaneous chloroform data in a similar concentration range.

In addition to quality assurance data from field samples, data from reproducibility of USEPA reference standards and laboratory calibration standards were compiled as shown for chloroform in Table C-1. At concentrations for which a large number of standards were analyzed, data indicate variability similar to that shown in field data in the same concentration range. USEPA reference standards containing chloroform at 68.5 ug/L were analyzed 83 times as part of the routine quality assurance program. The data were blank corrected. A mean value of 70.9 ug/L with a relative standard deviation of ± 14% resulted. The mean represented a relative error of + 4% from the true value as reported by USEPA. Calibration standards containing chloroform at 10 ug/L were analyzed 57 times as unknown samples by comparison to the programmed calibration standard as part of the routine quality assurance program. The data produced were blank corrected. A mean value of 9.4 ug/L with a relative standard deviation of ± 20% resulted. The mean represented a relative error of - 6% from the true value reported by the laboratory. These data indicate that quantification of chloroform standards at or above 10 ug/L were accurate within ± 6%. Repeatability (precision) of analyses was within ± 20%. Quality assurance data from the analyses of pure compounds in low organic water (Table C-1) only suggest the significance of data produced from the analyses of field samples. Quality assurance data from replicate analyses of field samples (Tables C-1 to C-3) are more meaningfully applied in determining the significance of sample data.

As a second example, quality assurance data in Table C-7 for chlorobenzene illustrate the significance applicable to data as concentrations approach the detection level. Analyses of 19 sets of field replicate samples indicate increasing variability of data with decreasing chlorobenzene concentrations. Six samples within sets producing chlorobenzene data in the 1.4 to 2.9 ug/L range, replicated within ± 29%. The variability of replication increased to ± 59% in six sets of samples producing data in a lower range of concentrations from 0.1 to 0.8 ug/L. Seven sets of samples producing chlorobenzene concentrations less than 0.1 ug/L varied ± 100% in replication. Thus, chlorobenzene concentrations of 1.0 ug/L and 2.0 ug/L in project samples could be differentiated, but concentrations of 0.1 ug/L and 0.2 ug/L could not be differentiated.

A comparison of the field quality assurance data to the data on precision of chlorobenzene from analyses of laboratory standards at concentrations below 1.0 ug/L indicates less variability in laboratory than in field samples; however, the evaluations at low concentrations were based on a small number of analyses of pure compounds in low organic water. When calibration standards containing chlorobenzene at 10 ug/L were analyzed 57 times, as part of the routine quality assurance program, a precision of ± 37% was obtained, a value similar to the ± 29% obtained for field samples in the concentration range of 1.4 to 2.9 ug/L.

Application of the significance of quality assurance data to total trihalomethane (TTHM) values must also be made for interpretation of instantaneous and terminal TTHM project data. Instantaneous and terminal TTHM data were compiled from analyses of replicate field sets and from replicate analyses of single field samples. The mean TTHM concentration of each data set was plotted versus the relative deviation of the set about the mean. The resulting levels of precision for 95% of the sample sets were ± 20% for instantaneous TTHM and ± 16% for terminal TTHM, as illustrated in Figures C-11 and C-12, respectively. These levels of variability generally agree with levels from replicate data sets of individual trihalomethane compounds at concentrations greater than 1.0 ug/L. These data indicate that sample instantaneous TTHM concentrations of 40 ug/L and 65 ug/L can be differentiated but instantaneous concentrations of 80 ug/L and 86 ug/L cannot.

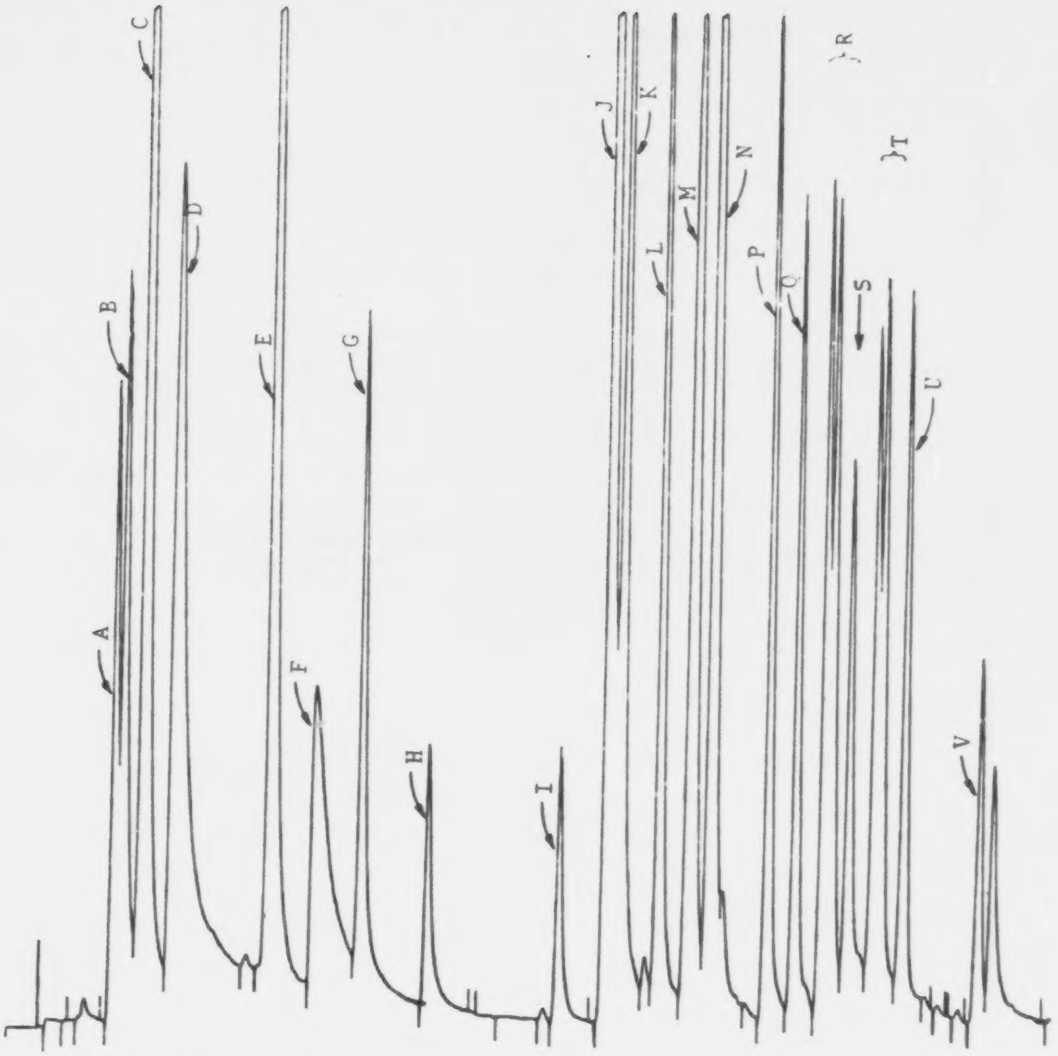
Quality assurance data from analyses of field samples and from analyses of standards and blanks are presented for each purgeable compound in Appendix C. These data must be carefully evaluated and applied to the interpretation of project sample data for each of the purgeable compounds.

Analytical Procedure for Base-Neutral Extractable Compounds

The basic and neutral organic Priority Pollutants extracted from a sample with methylene chloride under alkaline conditions are referred to within this report as base-neutral extractable compounds. The extraction procedure, as described in USEPA's Protocol,[8] was used with several laboratory modifications as detailed in Appendix D.[9]

Two groups of compounds were analyzed from an extracted and concentrated sample. One group, extractable halocarbons including specific pesticides, was analyzed by GC/Hall detector (GC/Hall). Individual compounds and their approximate lower levels of detection are listed in Table 5. Figure 6 is a representative GC/Hall chromatogram for a direct injection analysis of calibration standards, Figure 7 a chromatogram of a system blank, and Figure 8 a chromatogram of an extracted and concentrated sample.

The second group, non-halogenated extractable hydrocarbons, was analyzed by GC/flame ionization detector (GC/FID). Individual compounds and their approximate lower levels of detection are listed in Table 6. Figures 9, 10,



note: for reference code, see Table 5
J = hexachlorobenzene (internal standard)

Figure 6. Typical gas chromatogram of base-neutral extractable halogenated Priority Pollutants calibration standard using Hall detector.

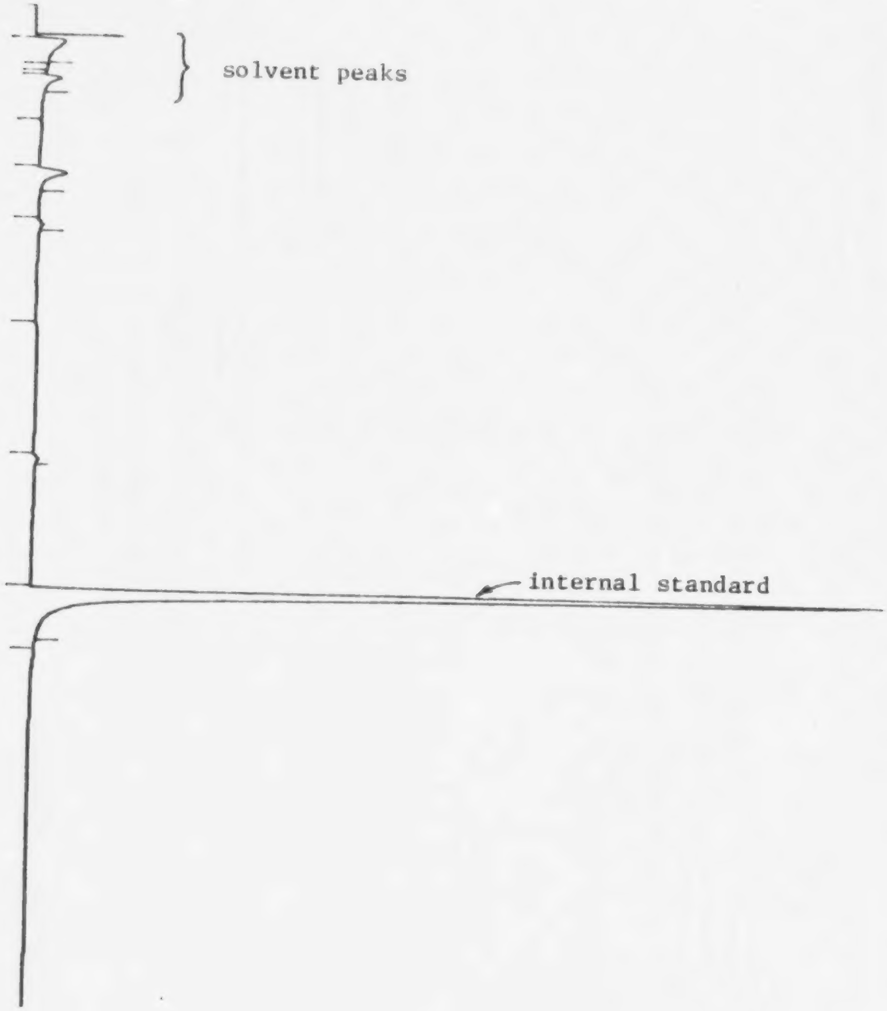


Figure 7. Typical gas chromatogram of base-neutral extractable solvent blank using Hall detector.

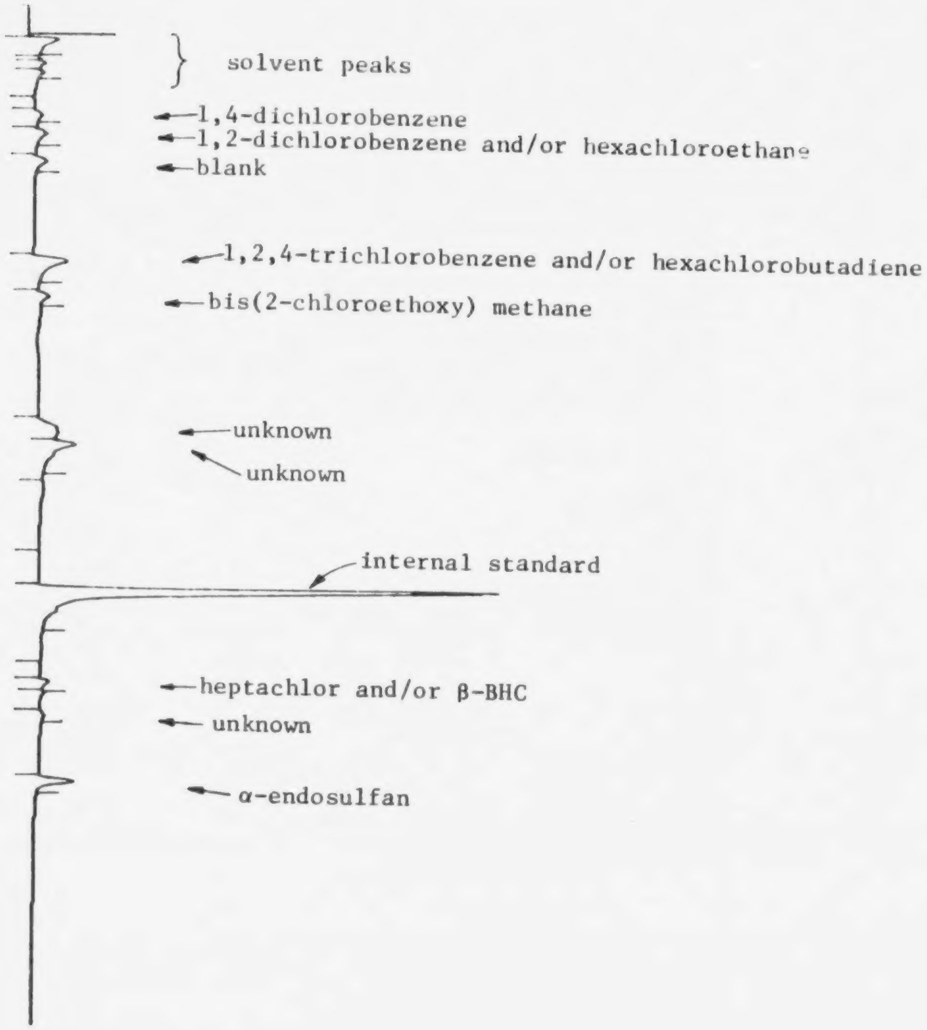


Figure 8. Typical gas chromatogram of base-neutral extractable sample using Hall detector.

TABLE 5. HALOGENATED BASE-NEUTRAL EXTRACTABLE PRIORITY POLLUTANTS GC/HALL DETECTOR AND 3,000 CONCENTRATION FACTOR

Reference Code	Compound	Approximate Lower Detection Level[a] ug/L
A	1,3-Dichlorobenzene	0.1
B	1,4-Dichlorobenzene	0.1
C	Hexachloroethane 1,2-Dichlorobenzene	0.1
D	bis(2-Chloroiosopropyl) Ether bis(2-Chloroethyl) Ether	0.2
E	1,2,4-Trichlorobenzene Hexachlorobutadiene	0.1
F	bis(2-Chloroethoxy)methane	0.1 - 0.2
G	Hexachlorocyclopentadiene	0.1 - 0.2
H	2-Chloronaphthalene	0.1
I	4-Chlorophenyl Phenyl Ether	0.1
K	4-Bromophenyl Phenyl Ether α-BHC	0.1
L	γ-BHC (Lindane) δ-BHC	0.1
M	Heptachlor β-BHC	0.1
N	Aldrin	0.1
P	Heptachlor Epoxide	0.1
Q	α-Endosulfan	0.1
R	Dieldrin DDE	0.1
S	Endrin	0.1
T	DDD β-Endosulfan	0.1
U	DDT	0.1
V	Methoxychlor	0.1 - 0.2

a = not corrected for extraction losses

and 11 are chromatograms of a direct injection calibration standard, a system blank, and an extracted and concentrated sample, respectively.

The method of qualitative determination differed for the two groups of extractable compounds. Compound identification by GC/Hall analysis was based on relative retention time match within ± 5% RRT of the corresponding compound in the calibration standard and an extracted internal standard of hexachlorobenzene in each sample. When the sample was analyzed by GC/FID, qualification was based on absolute retention time match within ± 5% of absolute retention times of standard peaks in the calibration chromatograms. Although the hexachlorobenzene internal standard did not elicit a sufficient response on the flame ionization detector for internal standard qualification, it did cause a small, integrable response that was used as an internal standard for relative retention time matching when chromatograms were reviewed by the project staff.

The recovery of these compounds by extraction was variable; therefore,

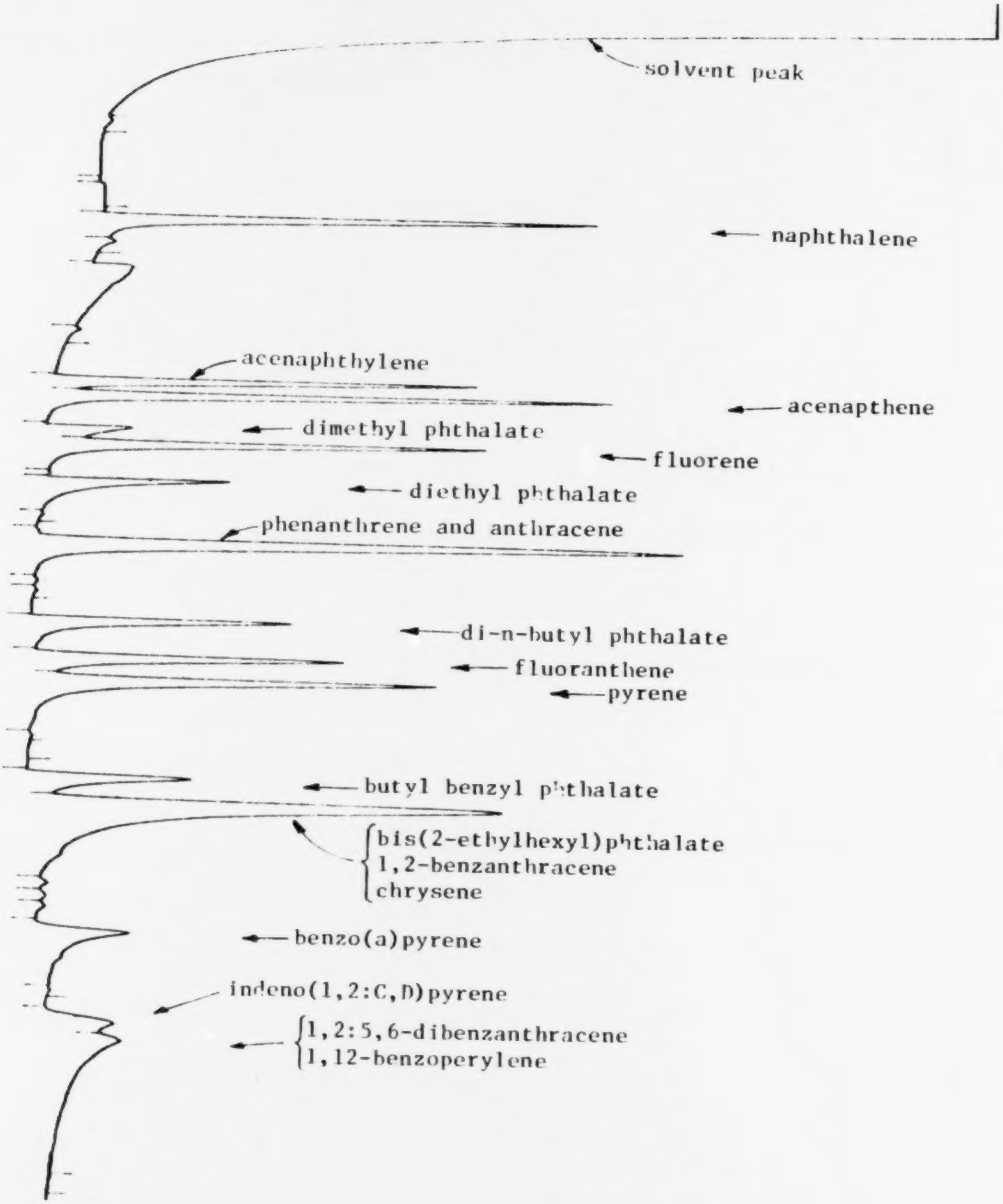


Figure 9. Typical gas chromatogram of base-neutral extractable Priority Pollutants calibration standard using flame ionization detector.

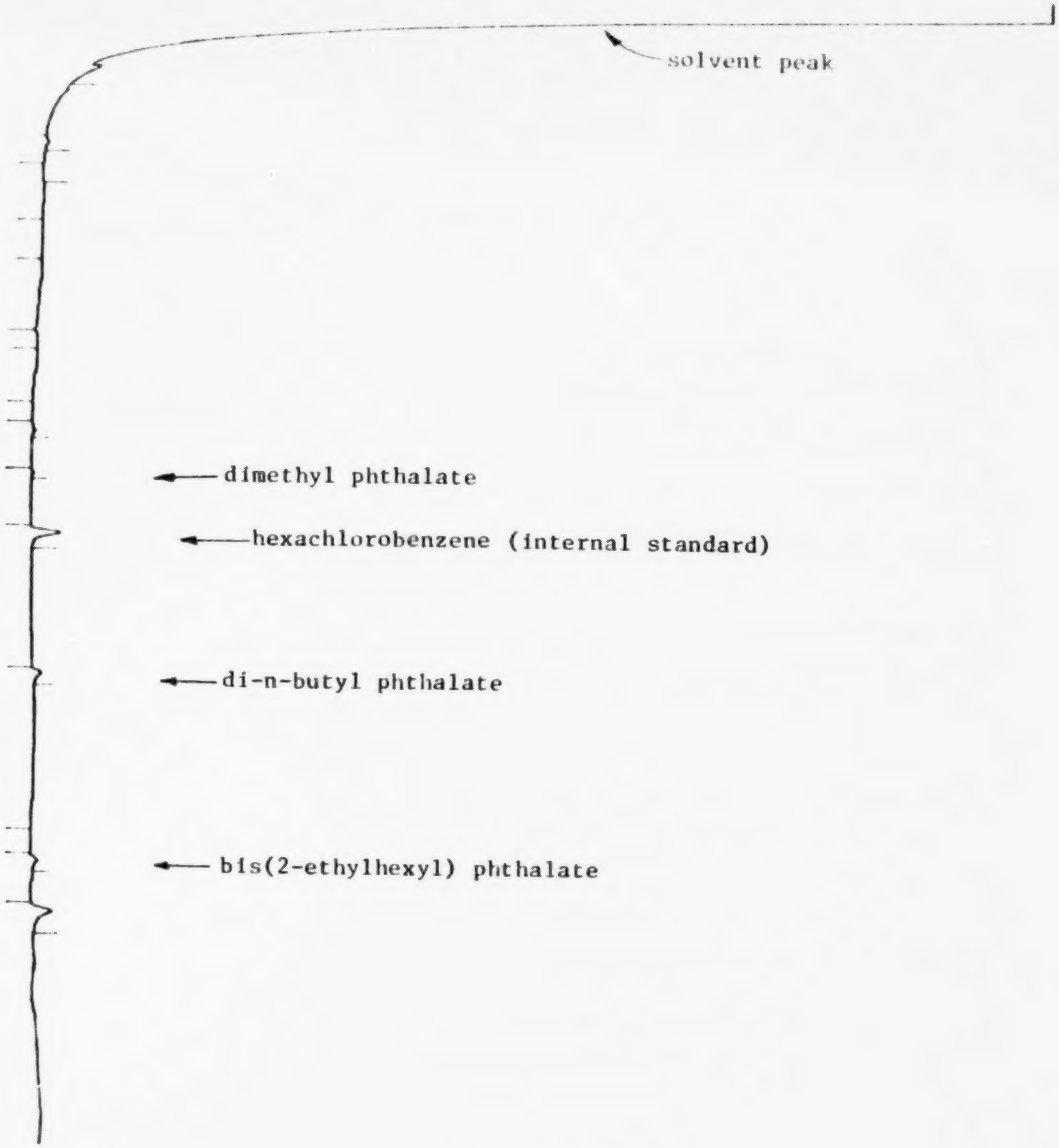


Figure 10. Typical gas chromatogram of base-neutral extractable solvent blank using flame ionization detector.

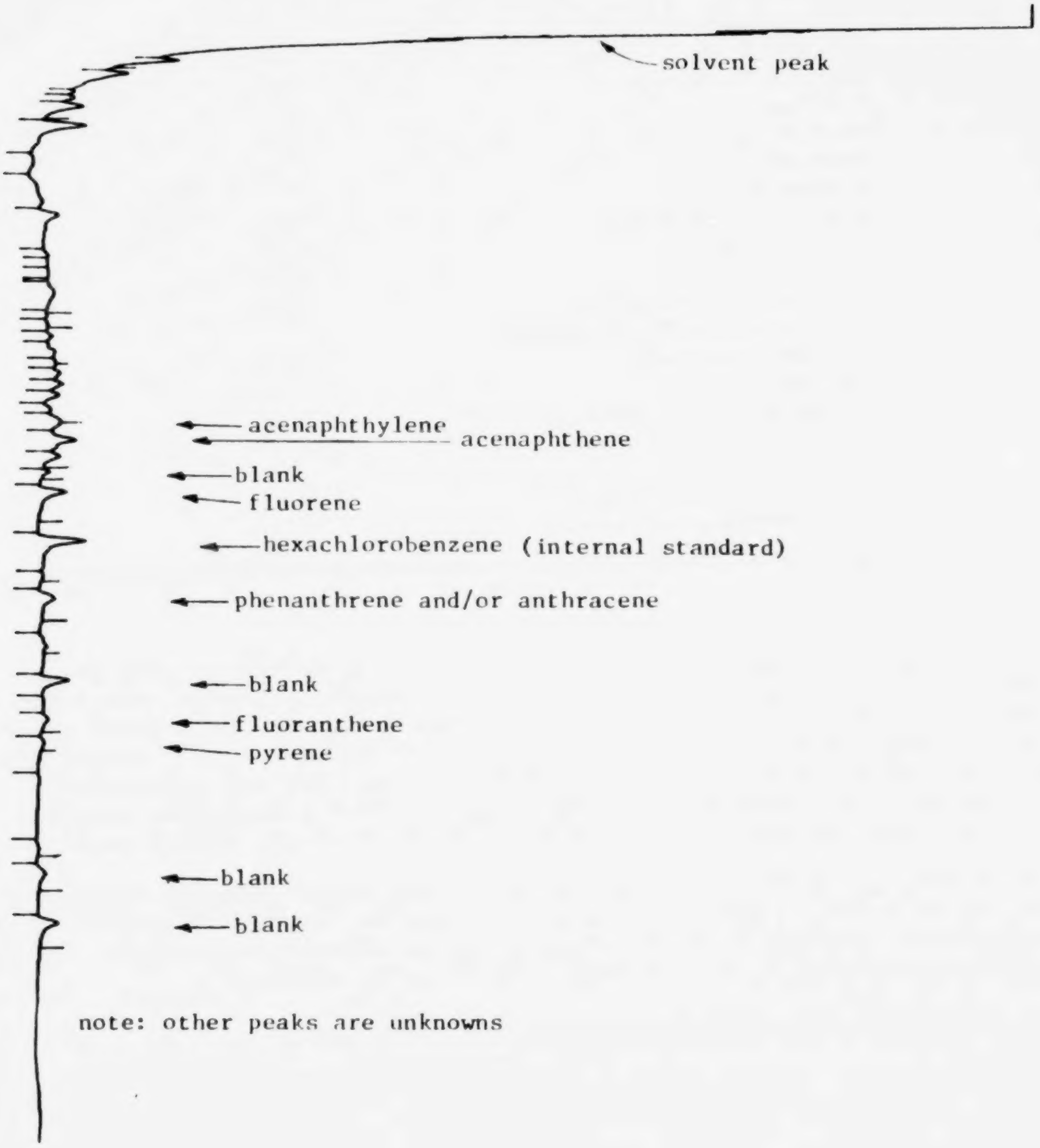


Figure 11. Typical gas chromatogram of base-neutral extractable sample using flame ionization detector.

TABLE 6. NON-HALOGENATED BASE-NEUTRAL EXTRACTABLE PRIORITY POLLUTANTS GC/FLAME IONIZATION DETECTOR AND 3,000 CONCENTRATION FACTOR

Compound	Approximate Lower Detection Level[a] ug/L
Naphthalene	0.5
Acenaphthylene	0.5
Acenaphthene	1.0
Dimethyl Phthalate	5.0
Fluorene	0.5
Diethyl Phthalate	2.0
Phenanthrene	1.0
Anthracene	
Di-n-butyl Phthalate	0.5
Fluoranthene	1.0
Pyrene	0.5
Butyl Benzyl Phthalate	2.0
bis(2-Ethylhexyl) Phthalate	1.0
1,2-Benzanthracene	
Chrysene	
3,4-Benzofluoranthene	5.0
11,12-Benzofluoranthene	
Benzo(a)pyrene	5.0
Indeno(1,2:C,D)pyrene	10.0
1,2:5,6-Dibenzanthracene	10.0
1,12-Benzoperylene	

a = not corrected for extraction losses

this procedure for base-neutral extractable Priority Pollutants must be considered semi-quantitative. Quantification was based on a comparison of the response of corresponding peaks in the concentrated sample extract and calibration chromatograms, and the concentration factor. The concentrations were not corrected for extraction losses. Both qualification and quantification were automatically handled by a Hewlett Packard 3380A programmable integrator[10] and were reviewed in each sample chromatogram by the project staff.

GC data generated for the base-neutral extractable compounds with the Hall and FI detectors are presumptive. In order to determine the validity of data produced by GC only, GC/MS confirmation attempts were essential. Section 7 discusses comparative GC and GC/MS data for each compound.

Quality Assurance for Base-Neutral Extractable Compounds

An extensive quality assurance program was necessary to ensure the significance and validity of the data.

Periodic Quality Assurance--

Approximate lower detection levels were established for routine analysis of the extractable compounds by direct injection of calibration standard compounds diluted by factors of two until an arbitrary area count fell below 1,000 units.

For the halogenated compounds, the lower detection levels by GC/Hall detection varied throughout the project and ranged from approximately 0.1 ug/L to 0.2 ug/L depending on the particular compound (Table 5). Validation of detection levels in this range was supplied by extraction recovery tests of calibration standard compounds analyzed by GC/Hall, and by GC/MS confirmation of GC/Hall data at the lower levels of detection for some, but not all, of the halogenated compounds.

For the non-halogenated compounds analyzed by GC/FID, the levels ranged from 0.5 ug/L to 10 ug/L depending on the particular compound (Table 6). Further validation of these levels was supplied by direct injection and extraction recovery tests of calibration standard compounds analyzed by GC/FID, and by GC/MS confirmation of GC/FID data at the lower detection levels.

Extraction recoveries of the base-neutral extractable Priority Pollutants at several concentrations were determined by spiking calibration standard compounds in methanol into three liters of low organic distilled water. Extraction was evaluated by averaging the recoveries of triplicate extraction and concentration tests. Values were corrected for interferences that occurred in blanks representative of three liters of low organic distilled water extracted and concentrated in an identical manner. Percent recoveries for each halogenated compound are given in Appendix E, Tables E-1 through E-20 and for the non-halogenated compounds in Appendix F, Table F-1.

Recoveries were based on extraction of calibration standard compounds from low organic distilled water and only suggest that similar recoveries occurred when extracting Priority Pollutants from field samples representing varied and complex waters. While extraction recovery tests from selected field waters rather than from distilled water would have been more representative, there was no assurance that a relatively small number of such recovery tests would have been representative of the hundreds of samples analyzed during the project.

The accuracy and precision of standards analyzed at several concentrations by direct injection were evaluated periodically and as part of a routine quality assurance program. The data are compiled in Appendix E, Tables E-1 through E-20, and Appendix F, Tables F-2 and F-3, for the halogenated and the non-halogenated base-neutral extractable Priority Pollutants, respectively. The results of the data indicate that concentrations were significant to two figures at the ug/L level. This level of significance was applied to field data.

Routine Quality Assurance--

A routine quality assurance program was found to be particularly important in the preparation of samples for the analysis of the extractable Priority Pollutants. Extraction of compounds from samples into solvent and concentration of the solvent were found to introduce significant levels of impurities causing interference in the GC/FID analyses. The purity of solvents was routinely evaluated as part of an evaluation of the entire analytical procedure that included glassware cleaning, solvent extraction, concentration, storage and analysis. This evaluation was conducted by analysis of solvent blanks handled in a manner identical to samples, i.e., volumes of solvent as specified in the procedure were introduced to extraction glassware, concentrated, exchanged for a second solvent, concentrated, stored and analyzed by both GC/Hall and GC/FID.

Solvent blank analyses identified an interference in the analysis of bis-chloroethers. This problem is detailed in Appendix G.

The daily quality assurance program for base-neutral extractable analyses was based on a group analysis concept. One bottle of methylene chloride contained sufficient volume for six extractions utilizing 550 mL each. Four samples and two control blanks were extracted from each bottle of solvent. Initial analyses of extracted and concentrated groups indicated that variability of interferences between the two blanks within a group was often high. Further, variability of blanks among groups was often high. Thus, the frequency of two blanks per extraction group was maintained in order to characterize the purity of each bottle of solvent and all analytical conditions associated with the procedure. Data was corrected in groups for solvent blank interferences specific only to a group. Data was statistically corrected for several groups for solvent blank interferences that occurred consistently.

Samples were extracted, concentrated, stored and analyzed in groups with associated solvent blanks. The daily GC/Hall and GC/FID analysis included the following components per group: four field samples, a direct injection calibration standard used to program the integrator for relative retention times and response factors, two solvent blanks, a previously analyzed field extract for comparative evaluations of day-to-day analytical conditions, and a direct injection calibration standard handled as an unknown to determine stability of the system for RRT and response factors. In addition, approximately ten percent of the field samples were submitted in replicate.

All quality assurance data were used daily to ensure that analytical conditions were within established control limits. All data were also compiled for determination of the significance of project sample data.

Application of Quality Assurance Data to Sample Data--

Accumulated quality assurance data from analyses of standard compounds extracted from distilled water, direct injected standard compounds handled as unknowns, replicate field samples, and replicate analyses of single field samples are presented in Appendices E and F for base-neutral extractable Priority Pollutants. These data define the significance of the project sample data.

Application of Quality Assurance Data for Base-Neutral Extractable Halocarbons--Two examples demonstrate the significance of this data.

The quality assurance data for 1,3-dichlorobenzene are presented in Appendix E, Table E-2. These data indicate that approximately 60% of the compound was extracted from distilled water; however, extraction recovery data only suggest that recovery of the compound by extraction from raw and treated field waters was similar. For example, when a concentrated extract of a field sample was analyzed for 1,3-dichlorobenzene, the indication is that the quantification represented approximately 60% of the field concentration. Further, the precision obtained from analyses of extracts from field replicate samples and from replicate analyses of extracts from single field samples indicates that concentrations of 1,3-dichlorobenzene above 0.1 ug/L reported in field extracts may be ± 58% to ± 100%. Thus, when 0.4 ug/L of 1,3-dichlorobenzene was detected in a field extract, extraction recovery data suggest that 0.6 ug/L to 0.7 ug/L may have been in the sample, and precision data indicate that an extract concentration of 0.4 ug/L could not be differentiated from extract concentrations of 0.3 ug/L or 0.6 ug/L.

The second example illustrates the implications of co-eluting compounds. The quality assurance data for co-eluting 1,2,4-trichlorobenzene and hexachlorobutadiene are presented in Appendix E, Table E-4. Because of co-elution, GC/Hall quantification was based on the assumption that both compounds were equally present. This assumption was valid for laboratory extraction and reproducibility tests, but not for analyses of sample extracts. Only GC/MS analyses of extracts determined whether one or both compounds were present. Thus, when 0.3 ug/L of 1,2,4-trichlorobenzene and/or hexachlorobutadiene were detected in a sample extract, and compiled GC/MS data consistently identified the Hall-detected peak as 1,2,4-trichlorobenzene and not as hexachlorobutadiene, the quantification at 0.3 ug/L, based on the assumption that both compounds were present, was only an estimated value. The true concentration of 1,2,4-trichlorobenzene could not be determined.

The importance of quality assurance data and its application to project data cannot be overemphasized. These data must be evaluated and applied to the interpretation of project sample data for any of the base-neutral extractable halocarbons.

Application of Quality Assurance Data for Non-Halogenated Base-Neutral Extractable Hydrocarbons--Quality assurance data were obtained from standard compounds analyzed by direct injection and from standard compounds extracted from distilled water. Quality assurance data from sets of field sample extracts were not obtained because GC/FID analyses of sample extracts produced little data above the approximate lower detection levels. Quality assurance data produced from standard compounds injected at 5.0 ug/L and 10 ug/L and analyzed as unknown samples are contained in Appendix F, Tables F-2 and F-3.

Data produced from analysis of standard compounds at 1.5 ug/L and 10 ug/L extracted from distilled water are presented in Appendix F, Table F-1. Although variability of extraction recoveries for standard compounds analyzed in triplicate on any one day was low, variability between tests run on different days during the project was very high. These data are not sufficient to establish the relationship between the levels of compounds in field extracts and the levels in field waters. The variability of recoveries only suggests that extraction recoveries of project samples were also highly variable.

Attempted Analysis of Base-Neutral Extractable Nitrogen-Containing Hydrocarbons

Analyses were attempted for nitrogen-containing base-neutral extractable Priority Pollutants by GC/alkali detector. This analytical task was abandoned, however, because GC/alkali detector data could not be supported by GC/MS. Appendix H details the attempted analyses of these compounds.

Mass Spectrometer Analytical Procedures

Gas chromatography/mass spectrometry (GC/MS) verification of GC/Hall or GC/FID data was done using the USEPA Protocol.[8] Details of the laboratory's MS equipment and procedures are given in Appendix I.

GC/MS support of GC data was used in several ways. Requests for GC/MS confirmation were based on the need to define the validity of GC/Hall or GC/FID presumptive identification of Priority Pollutants. GC/MS confirmations of these compounds at concentrations close to the GC/Hall and GC/FID approximate lower levels of detection were frequently made. As a quality control measure, GC/MS searches were also conducted for compounds not identified by GC/detector. GC/MS was used to identify non-halogenated, base-neutral extracted hydrocarbon Priority Pollutants at concentrations below the GC/FID lower level of detection. For the halogenated base-neutral extractable compounds, however, the GC/MS and GC/Hall lower levels of detection were approximately the same.

Although the characterization of selected organic compounds in project samples was the primary objective, GC/MS identification of frequently occurring unknown compounds was also attempted.

Qualitative and Quantitative Determination--

Characteristic masses or mass ranges as given in the USEPA Protocol[8] were used for qualitative and quantitative determinations of project compounds. Generally, in support of GC identifications at concentrations in excess of one ug/L, extracted ion current profiles (EICP) were obtained in the scanning mode for GC/MS confirmation or quantification of GC/Hall or GC/FID data. An EICP is defined as a reduction of GC/MS data obtained from continuous, repetitive measurement of spectra by plotting the change in relative abundance of the primary or secondary ions as a function of time. A positive GC/MS confirmation was based on the following conditions as recommended in the Protocol: the time at which the peak occurred was within a retention time match of ± 1 minute; a characteristic primary and secondary ion for a compound were found to maximize in the same spectrum; and the ratio of the primary and secondary ion agreed with relative intensities established for the compound.

In support of GC identifications at concentrations below one ug/L, GC/MS selected ion monitoring (SIM) was used. SIM is defined as a measurement of the GC/MS response at one or several characteristic masses in real time. Again, a primary and secondary ion were used for confirmation in the SIM mode.

GC/MS-SIM was the approach most often used in support of GC data for project compounds, other than the trihalomethanes in in-plant or finished water samples, because GC data were often in the 0.1 to 1.0 ug/L range of concentrations. Identification of a recurring unknown peak in project samples was attempted only when a concentration of approximately one ug/L was present, because the GC/MS-scanning mode was needed for generation of a total ion current profile.

UTILITY LABORATORIES

Sample Scheduling

Schedules were established for all organic, inorganic and bacteriological sampling. Early in the project, each utility was visited, plant hydraulics were discussed, sample locations were selected, and sample collection was scheduled. Sample collection times were designed to follow the flow of a theoretical plug of water through the plant. If dictated by changing hydraulics, utility personnel modified pre-scheduled sample collection times.

Organic Sampling and Handling

The collection and handling of samples for organic analysis were done by utility personnel using procedures specified by the project staff and sample bottles prepared and shipped by the contract laboratory. Sample bottles were stored at the utility in shipping containers until used. Samples were collected according to the procedures detailed in Appendix J. Purgeable and extractable samples were refrigerated in the dark until shipment. After addition of excess chlorine, terminal level purgeable samples were stored in the dark for seven days at a temperature approximating that of the utility's finished water, quenched with thiosulfate, and refrigerated in the dark until shipment. Time in refrigeration for all samples at the utility ranged from one to seven days. All samples were shipped in insulated containers with frozen ice packs via air transport to the contract laboratory. Time in transit between the utility and the laboratory was typically one or two days but occasionally as long as four days.

Inorganic Water Quality Analyses

At each organic sample location, waters were sampled by utility personnel for analyses of background water quality parameters. All utilities analyzed for physical and chemical parameters known to affect the THM reaction, i.e., pH, temperature, chlorine residuals. Utilities participating in THM control studies performed additional sampling and analyses for other parameters necessary for evaluation of the control, i.e., ammonia, turbidity, taste, odor, iron, manganese, chlorine dioxide, etc. Methods used for measurement of those parameters were those routinely used by the utility and detailed in Standard Methods.[11] The only exception was the utilization of an analytical procedure[12] for the measurement of chlorine, chlorine dioxide and chlorite in sample waters.

Bacteriological Water Quality Analyses

Bacteriological monitoring was done by utility personnel during each THM control study to ensure that the quality of the finished water was not compromised by the treatment modification being studied. At each organic sample location, waters were sampled for bacteriological analyses. Total coliform (TC) and standard plate count (SPC) analyses were performed according to Standard Methods.[11]

Tests were also conducted to evaluate a membrane filter procedure using m-SPC agar for all treated samples in which low standard plate count densities were expected. This procedure[13] permitted the examination of sample volumes greater than one mL, the sample limitation of the SPC pour plate technique. The procedure is detailed in Appendix K. A USEPA microbiologist visited the utilities performing these analyses to review bacteriological procedures and to familiarize utility personnel with the membrane filter SPC procedure.

Water quality parameters that affect disinfection conditions (turbidity, temperature, pH, ammonia) and residual concentrations of disinfectants (chlorine, chlorine dioxide) were evaluated for each bacteriological sample.

Operational Data

During THM control studies, utility personnel provided the operational data necessary for evaluation of the control, i.e., chemical feed rates, filter/adsorber hydraulics, filter/adsorber backwashing history, etc.

SECTION 6

TRIHALOMETHANE TREATABILITY STUDIES

GENERAL

One project objective was to evaluate existing and modified utility water treatment practices to control trihalomethane concentrations. Trihalomethanes result from the reactions[5]:

$$Cl_2 + \text{precursor} \rightarrow CHCl_3$$

$$Cl_2 + \text{precursor} + Br^- + I^- \rightarrow \text{other THMs}$$

To control THMs, three approaches are possible. The reaction can be allowed to proceed with the subsequent removal of the THMs, steps can be taken to prohibit the reaction from proceeding, or both approaches can be employed.

USEPA examined such controls on pilot plant and bench scales.[6] This project studied full scale applications of those controls to reduce TTHM concentrations in clear well effluents. Another aspect of the control studies was to investigate the effect of treatment on precursor levels as measured by the parameters THMFP and terminal TTHM. The modification implemented to control THMs at a utility was the decision of the project staff and the utility personnel after studying the adaptability of the utility's treatment to modification.

There were other aspects of the THM treatability studies. Evaluations of treatment modifications were made to ensure that treatment changes did not compromise the bacteriological integrity of the finished water. Evaluations of halocarbons other than THMs were conducted to assess the effect of existing and modified treatment on these compounds. Bromide and iodide concentrations were not determined.

Finally, it was expected that water quality parameters (pH, temperature and chlorine levels) and chemical application rates (chlorine, powdered activated carbon and chlorine dioxide) that can affect the THM reaction[5,6] would vary during the study period. Water quality data and chemical application rates are discussed only when their variation may have had a significant effect on THM formation.

DATA INTERPRETATION

To evaluate a treatment modification for THM control or to evaluate the control of other Priority Pollutants, comparisons were made of the means of data sets, and of data from individual samples. Such comparisons were based on statistical evaluations which determined means or individual data to be different or to be non-differentiable.

Comparison of Mean Data

To evaluate comparatively routine and modified treatment for control of trihalomethanes, the significance of the statistical parameters used in the evaluation was defined.

A comparison of data from two periods of treatment, i.e., finished water TTHM during routine and modified treatment, was based on mean values obtained from averaging data representing the study periods. The significance of each mean value was dependent on the variability of the set of data used in its calculation. To establish whether the means of two distributions (study periods) were different, a 90% confidence interval for the difference between the means was calculated using a "t" distribution. The confidence interval was established at a 90% level rather than at some greater level. Calculation of the interval for the difference between means is based on three factors: the number of samples representing the distributions, the variation in sample data within each distribution, and the level of confidence at which a statement of difference is to be made. Each treatment period was represented by a relatively small number of samples. Cost and time demands for increasing the number of samples and analyses were prohibitive. Variability of raw water precursor over a sampling period could not be predicted or controlled. Therefore, in order to differentiate between mean values within the design of the study, a 90% confidence interval was chosen.

On the basis of the calculated interval, it was established for each comparison of means whether the values were statistically different.

Comparison of Data from Individual Samples

A detailed discussion of significance applicable to interpretation of data produced from individual samples is presented in Section 5, pages 20 to 22. As stated in that section, a comparison of data from single samples, i.e., adsorber influent and effluent samples collected in plug flow sequence, was based on the significance of data obtained from analyses of numerous sets of field replicates and of replicate analyses of single samples. The significance of data varied for different compounds and for different concentration ranges.

THE EFFECT OF CHLORINE APPLICATION POINTS ON TRIHALOMETHANE FORMATION

General

An examination of the THM reaction

$$Cl_2 + \text{precursor} + Br^- + I^- \rightarrow \text{THMs}$$

indicates that if the chlorination practice were discontinued, the reaction would not proceed. Unless an equally effective alternative disinfectant is used, elimination of chlorination for THM control is not acceptable. However, reduction of precursor levels prior to chlorination is a viable approach to THM control. USEPA has demonstrated on the pilot plant scale that coagulation and settling reduced precursor levels.[6] At three project utilities, the initial chlorine application point was moved further into the treatment process in order to reduce precursor levels prior to chlorination and to reduce the in-plant THM reaction time. This means of control was studied at the Pittsburgh Department of Water, the Cincinnati Water Works and the Wheeling Water Department.

At each utility, raw, in-plant, and finished waters were sampled two to four times weekly for periods of one to two weeks during both routine and modified treatment studies. For each sample day, waters were sampled following a theoretical plug from raw water through the plant to the clear well.

Pittsburgh Department of Water

Routine and Modified Treatment--

Pittsburgh routinely chlorinated untreated Allegheny River water. For THM control, the chlorine application was moved to a point immediately following coagulation and clarification. The utility's treatment scheme and water quality data representative of two weeks of sampling during routine treatment and two weeks of sampling during modified treatment are presented in Figure 12.

During the study period, 75% of the clarified water received 13 hours of settling and the remaining 25% bypassed settling. These two waters were mixed prior to filtration. During modification, water influent to the filter was a mix of chlorinated settled water and unchlorinated clarified water.

Evaluation of Trihalomethane Control--

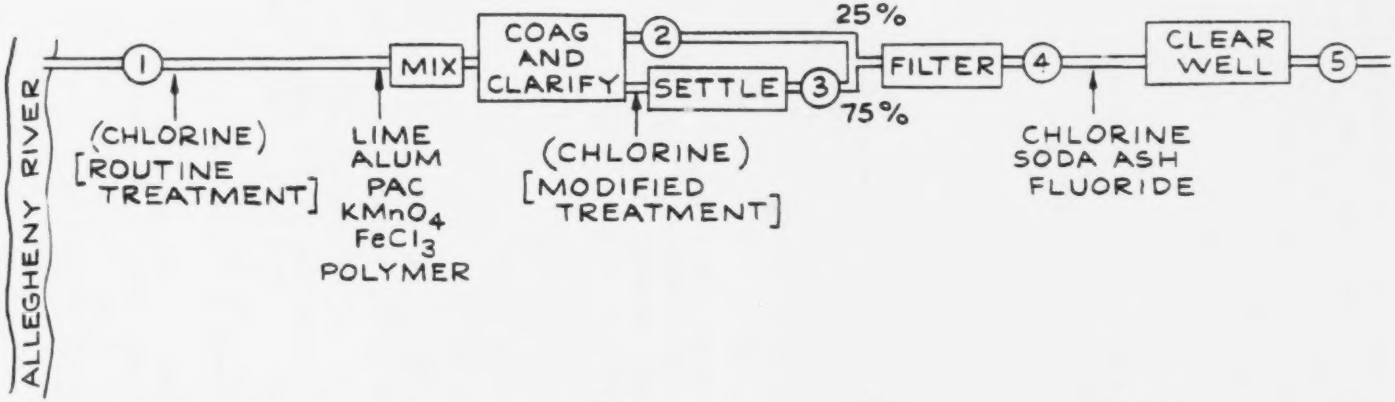
Instantaneous and terminal TTHM concentrations based on data from two weeks of sampling with raw water chlorination and from two weeks with clarified water chlorination are illustrated in Figure 13.

A statistical comparison of mean terminal TTHM concentrations indicates that raw water precursor levels could not be differentiated during the two study periods.

For both study periods, raw and clarified mean terminal TTHM concentrations could be differentiated, but clarified and finished mean terminal TTHM concentrations could not be differentiated. Thus, coagulation and clarification reduced precursor levels but subsequent treatment likely did not.

Figure 12 indicates that mean raw water turbidity levels of 7.2 and 7.1 NTU were comparable over the two study periods and that coagulation and clarification reduced turbidities to mean levels of 0.8 and 1.0 NTU. These data show that as coagulation and clarification reduced turbidity, it also reduced precursor levels; however, when turbidities fell below 1.0 NTU, further reduction in precursor levels could not be observed.

Mean raw water turbidity and raw water terminal TTHM concentrations were



PARAMETER	①	②	③	④	⑤
TIME, HR	0	2	15	16	32
TEMP, °C	24/21	-	-	-	-
TURB, NTU	7.2/7.1	0.8/1.0	0.6/0.9	<0.1/<0.1	<0.1/<0.1
pH	7.1/7.1	8.8/8.8	8.8/8.8	8.8/8.8	8.0/8.2
FREE Cl_2, PPM	-	0.2/<0.1[a]	0.2/0.3	0.1/0.1	0.1/<0.1
TOTAL Cl_2, PPM	-	0.6/0.2[a]	0.3/0.6	0.3/0.4	0.2/0.2
TC/100 mL	6200/6300	<1/<1	<1/<1	<1/<1	<1/<1
SPC/mL	-	31/230	3/5[b]	3/<1	4/<1

LEGEND

ROUTINE TREATMENT/MODIFIED TREATMENT
○ = SAMPLE POINT
(OPTIONAL FEED)

NOTES

a = MnO_4^- INTERFERENCE
b : EXCLUDING SINGLE REPORT OF 140

Figure 12. Treatment at Pittsburgh Department of Water, 228,000 cu m/day (60 MGD), water quality data (mean values), September - October 1978.

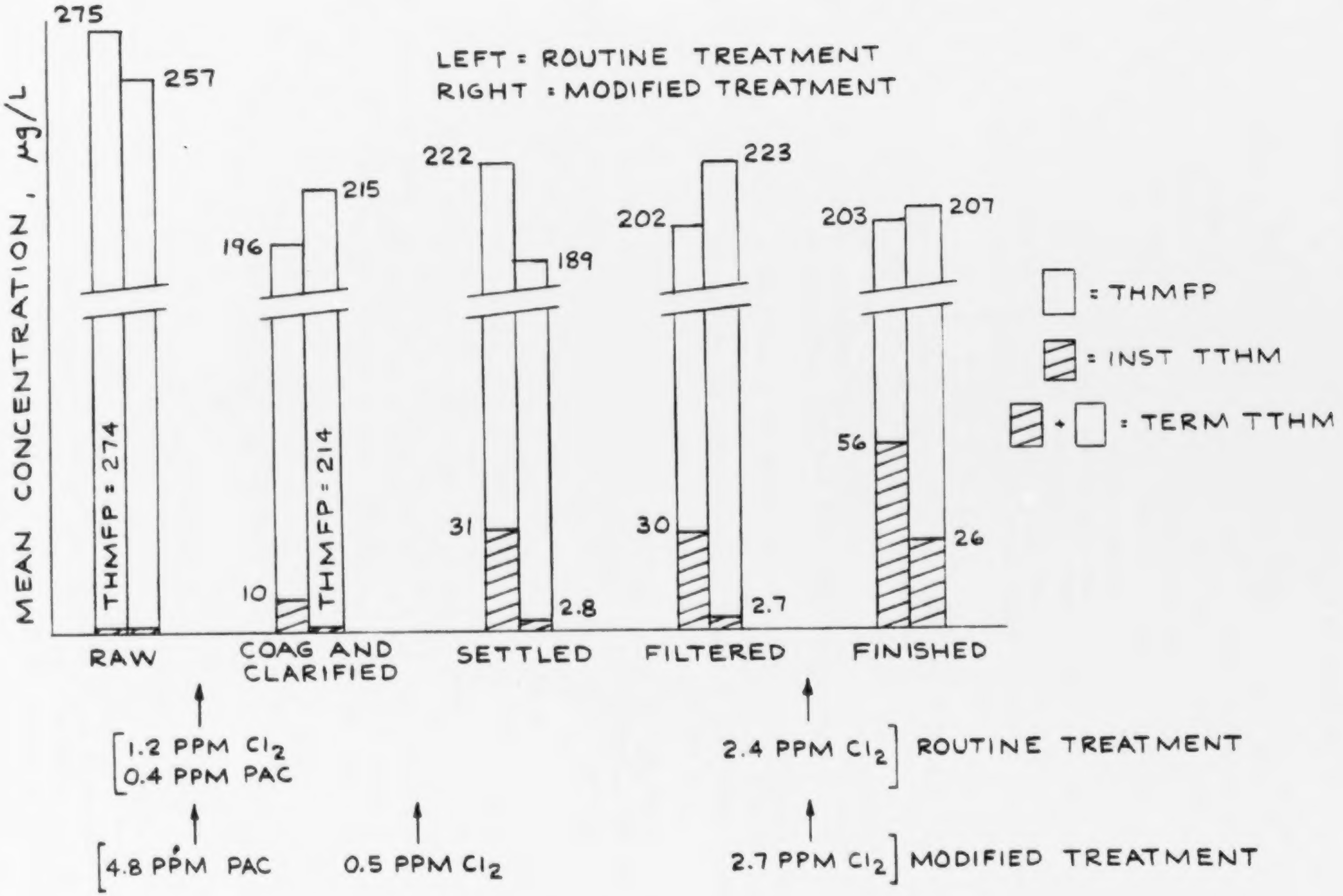


Figure 13. Trihalomethane formation (mean values), Pittsburgh Department of Water, 228,000 cu m/day (60 MGD), September - October 1978.

comparable during the two study periods; however, on a day-to-day basis, both fluctuated and not always in the same direction.

As shown in Figure 13, chlorination of raw water with a mean THMFP of 274 ug/L (275 ug/L term TTHM - 1 ug/L inst TTHM = 274 ug/L THMFP) resulted in 56 ug/L mean instantaneous TTHM in the finished water. Chlorination of clarified water with a mean THMFP of 214 ug/L resulted in 26 ug/L finished water TTHM. There was a reduction in the percent formation of finished water TTHM from available raw water precursor. Of the THMFP available in the raw water, 20% reacted to form TTHM in the finished water during routine treatment (56 ug/L finished water inst TTHM/274 ug/L raw water THMFP). During modified treatments, 10% of the available THMFP in the raw water reacted to form finished water TTHM. Moving the chlorine application point to a location with reduced THMFP resulted in significantly lower finished water trihalomethane concentrations.

Other factors that may have contributed to lowered TTHM formation were a reduction of two hours in available THM reaction time and a slight reduction in chlorine feed. The effect of mixing 75% chlorinated settled water with 25% unchlorinated clarified water could no be evaluated because the resulting instantaneous TTHM concentrations were low and could not be differentiated.

Moving the chlorine application point to a water with reduced chlorine demand also resulted in a savings in chlorine feed (1.2 mg/L to 0.5 mg/L) when attempting to maintain 0.1 mg/L free chlorine in the water applied to the filters.

A taste and odor incident related to the source water necessitated an increase in the use of powdered activated carbon (PAC) during the period when chlorine was applied to clarified water. This increase (0.4 mg/L mean to 4.8 mg/L mean) apparently contributed little to the reduction in finished water TTHM concentration. Although 4.8 mg/L was the mean PAC feed for the period, the range was 2.0 to 6.7 mg/L. These varying PAC feeds had no significant effect on instantaneous TTHM concentrations (2.7 ug/L mean) for filtered water, i.e., the last process location where water-PAC contact could have occurred. The effect of increased PAC (0.4 mg/L mean to 4.8 mg/L mean) on precursor levels could not be assessed. Reduction in precursor levels was, to a great extent, attributable to coagulation and clarification; the effect, if any, of PAC could not be evaluated.

As shown in Table 7, a change in the chlorine application point had no significant effect on the ratio of individual THM compounds found in the finished water.

Evaluation of Other Priority Pollutants--

This study was conducted in September of 1978 following the year during which monthly sampling was conducted at all utilities. Monthly data had indicated that other volatile and extractable halocarbons (Tables 1 and 2) occurred infrequently at Pittsburgh at concentrations where precision of field data was highly variable (Appendices C and E); therefore, analyses for these compounds were not conducted during this study.

TABLE 7. RATIO OF INDIVIDUAL TRIHALOMETHANES TO TOTAL TRIHALOMETHANES IN THE CLEAR WELL (%), PITTSBURGH DEPARTMENT OF WATER (INSTANTANEOUS MEAN VALUES)

	Treatment	
Compound	Routine (raw water chlorination) (September 6-16, 1978)	Modified (clarified water chlorination) (September 20-October 2, 1978)
Chloroform	19%	22%
Bromodichloromethane	29%	27%
Dibromochloromethane	37%	38%
Bromoform	15%	13%
Dichloroiodomethane	1%	1%
inst TTHM[a]	56 ug/L	26 ug/L

[a]GC/Hall detector

For a short period in September, however, a volatile halocarbon which was GC/MS confirmed as tetrachloroethylene was reported at high concentrations. These data, shown in Table 8, indicate a passing slug of the compound in the river and show a reduction in concentration when comparing raw and finished waters. However, the variable nature of a slug, the precision of tetrachloroethylene concentrations at the reported levels (± 25% to ± 32%, Appendix C, Table C-15), and the fact that data exist for only two sample sequences suggest caution in concluding that treatment lowered tetrachloroethylene concentrations.

TABLE 8. TETRACHLOROETHYLENE CONCENTRATIONS PITTSBURGH DEPARTMENT OF WATER

	Concentration[a], ug/L			
Water	Sep 6-13	Sep 14-15	Sep 15-16	Sep 20-Oct 2
Raw	1.0	64[b]	17	1.0
Clarified		20	27	
Settled		27	11	
Filtered		29	11	
Clear Well		22	8.2	

[a]GC/Hall detector

[b]GC/MS confirmed as tetrachloroethylene

Evaluation of Trihalomethanes in Finished Water Open Reservoir--

Pittsburgh has three large open reservoirs in the distribution system. One of these was sampled for this study. It has been described in detail by other researchers.[14] The irregular shape and numerous effluent points made it difficult to select sampling times based on plug flow through the reservoir. The tetrachloroethylene incident demonstrated that the selected times for reservoir sampling relative to times for clear well sampling were in error. Two phenomena may have affected instantaneous TTHM levels in the open reservoir: increased formation from periodic chlorination and volatilization of THMs to the atmosphere. Instantaneous and terminal TTHM concentrations for the clear well and reservoir are given in Table 9. Statistical comparison of these mean

TTHM concentrations indicates no difference between clear well and open reservoir waters but it should be noted that sample times for these two locations were not in plug flow agreement.

TABLE 9. TTHM CONCENTRATIONS,[a] ug/L, PITTSBURGH DEPARTMENT OF WATER (MEAN VALUES)

	Water		
Parameter	Clear Well	Open Reservoir	Treatment
inst TTHM	56	53	Routine (raw water chlorination, September 6-September 19)
term TTHM	203	197	
inst TTHM	26	27	Modified (clarified water chlorination, September 20-October 6)
term TTHM	207	210	

[a] GC/Hall detector

Bacteriological Evaluation--

A comparison of the bacteriological conditions during the two periods of sampling was made to ensure that treatment modifications did not compromise the bacteriological integrity of the finished water. Total coliform and standard plate count densities obtained for both periods are presented in Figure 12. These data indicate that raw water chlorination resulted in a reduction of the mean raw water total coliform density from 6,200/100 mL to <1/100 mL after clarification. A similar reduction of raw water total coliform density from mean values of 6,300/100 mL to <1/100 mL is indicated after clarification without raw water chlorination. Thus, clarification in combination with application of powdered activated carbon and permanganate was as effective in coliform reduction as raw water chlorination and clarification in combination with PAC and permanganate application. Although permanganate was applied at approximately 1 mg/L for manganese control during the study, it probably contributed to disinfection.

The chlorine disinfection conditions were more favorable during modified treatment because chlorine was applied to a clarified water of one turbidity unit as compared to the routine application of chlorine to a more turbid raw water.

The delay in chlorine application caused a parallel delay in reduction of the general bacterial population as measured by the standard plate count. After the processes of chlorination and clarification, the mean standard plate count density was 31 bacteria/mL; after clarification alone, the mean density was 230/mL.

The quality of the finished water was not altered by the delay in chlorination. During both periods of study, bacteriological conditions in the finished water were satisfactory, i.e., total coliform and standard plate count densities complied with the 1975 USEPA Interim Drinking Water Standard[15] of <1 coliform colony/100 mL and the recommended limit for the standard plate count of <500 organisms/mL.

Findings--

1. Trihalomethanes were formed during treatment after chlorine was

applied.

2. As clarification reduced turbidity to 1.0 NTU, it also reduced precursor levels. When turbidities fell below 1.0 NTU, further reduction in precursor levels could not be observed.

3. Moving the chlorine application point from raw water to clarified water resulted in chlorinating a water of lower THMFP.

4. Moving the chlorine application point to a better quality water in terms of reduced THMFP resulted in significantly lower finished water trihalomethane concentrations.

5. Moving the chlorine application point from raw water to clarified water resulted in a savings in chlorine feed.

6. Moving the chlorine application point reduced the in-plant THM reaction time 6% and had no significant effect on the ratio of individual THM compounds found in finished water.

7. A tetrachloroethylene spill was observed on the Allegheny River with concentrations in the plant reaching 60 ug/L.

8. Permanganate, flocculant, and PAC application followed by clarification were as effective in coliform reduction as chlorine applied with the other materials prior to clarification.

9. Moving the chlorine application point caused a delay in reduction of the general bacterial population as measured by the standard plate count, but the bacterial quality of the finished water was not altered.

Cincinnati Water Works

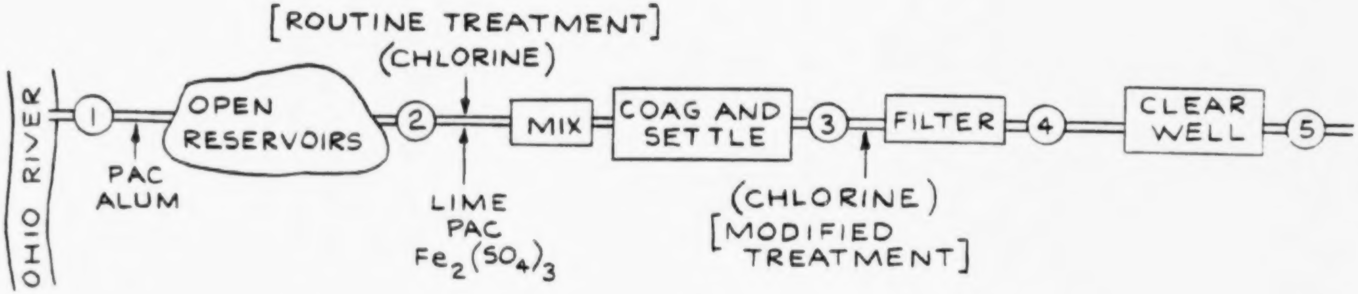
Routine and Modified Treatment--

The city of Cincinnati stores Ohio River water in a large, open reservoir where it is treated with a coagulant. Other treatment chemicals and chlorine are routinely added ahead of in-plant treatment processes. Relocation of this chlorine application point to the effluent from the settling basins was studied. The treatment schematic and water quality data representing two weeks of routine treatment sampling and two weeks of modified treatment sampling are presented in Figure 14.

Evaluation of Trihalomethane Control--

A problem at the contract laboratory resulted in a considerable loss of project samples collected during September and October 1977--the time of this study. Consequently, instantaneous and terminal TTHM data presented in Figure 15 are mean values for 80% of the samples collected during routine treatment and 60% of the samples collected during modified treatment.

A statistical comparison of mean terminal TTHM concentrations indicated a difference in raw water precursor levels between routine and modified treatment study periods. During the two-week period when reservoir settled raw



PARAMETER	①	②	③	④	⑤
TIME, HR	-48	0	4	4.5	7.5
TEMP, °C	18/22	-	-	-	-
TURB, NTU	32/14	1.0/0.8	1.2/1.0	0.1/<0.1	0.1/<0.1
pH	7.3/7.6	7.0/7.2	8.5/8.1	8.3/8.1	8.7/8.2
FREE Cl_2, PPM	-	-	1.8/-	1.6/1.8	1.5/1.4
TOTAL Cl_2, PPM	-	-	2.0/-	1.8/2.0	1.6/1.5
TC/100 mL	9600/84000	220/2400	<1/1400	<1/<1	<1/<1
SPC/mL	-	-	500/5500	<1/15	5/<1

LEGEND

ROUTINE TREATMENT/MODIFIED TREATMENT
○: SAMPLE POINT
(OPTIONAL FEED)

Figure 14. Treatment at Cincinnati Water Works, 560,000 cu m/day (150 MGD), water quality data (mean values), September - October 1977.

water was chlorinated, the mean raw water terminal TTHM concentration was 508 ug/L and mean raw water turbidity was 32 NTU. During the two-week period when in-plant settled raw water was chlorinated, the mean raw water terminal TTHM concentration was 309 ug/L and the mean raw water turbidity was 14 NTU.

During the four-week period, reservoir settling reduced turbidity to levels of approximately 1.0 NTU. At the same time, reservoir settling reduced precursor levels an average of 31% (mean terminal TTHM from 508 ug/L to 343 ug/L during the two-week period of routine treatment and mean terminal TTHM from 309 ug/L to 215 ug/L during the two-week modified treatment period). During the four-week period, subsequent treatment, including in-plant coagulation and settling, did not significantly reduce precursor levels. During the routine treatment period, mean terminal TTHM concentrations of 343 ug/L and 338 ug/L could not be differentiated. During modified treatment, mean terminal TTHM concentrations of 215 ug/L and 232 ug/L could not be differentiated. Thus, 48 hours of alum enhanced reservoir settling reduced precursor levels but subsequent treatment, including in-plant coagulation and settling, had little, if any, effect on precursor levels. These data suggest that as reservoir settling reduced turbidity it also reduced precursor levels but that when turbidities had been reduced to levels of approximately 1.0 NTU, further reduction in precursor levels could not be observed.

Figure 15 indicates that when chlorinating reservoir settled water with a mean THMFP concentration of 342 ug/L, a mean of 106 ug/L instantaneous TTHM resulted in the finished water. When chlorinating in-plant settled water with a mean THMFP concentration of 223 ug/L, a mean of 65 ug/L TTHM resulted in the finished water. While it appears that moving the chlorine application point to a better quality water in terms of THMFP resulted in reduced finished water TTHM concentrations (106 ug/L to 65 ug/L), an inspection of the percent formation of finished water instantaneous TTHM from available raw water precursor indicates that a reduction did not likely result. Of the 507 ug/L THMFP available in the raw water during the period of routine operation, 21% formed finished water instantaneous TTHM (106 ug/L finished water inst TTHM/507 ug/L raw water THMTP). Of the 308 ug/L raw water THMFP available during the period of modified treatment, 21% again reacted to form TTHM in the finished water. These data suggest that the reduction in finished water instantaneous TTHM during modified treatment was attributable to significantly lower raw water precursor levels during that period. During both routine and modified treatment, significant reduction in precursor did not occur beyond reservoir settling. Thus, moving the chlorine application point to an in-plant settled water resulted in chlorinating a water of lower THMFP only because precursor levels were significantly lower during that time. The decrease in THM reaction time from $7\frac{1}{2}$ to $3\frac{1}{2}$ hours had no apparent effect in limiting THM formation because per cent formation relative to raw water precursor was unchanged.

These data demonstrate the importance of the terminal TTHM and THMFP parameters in evaluating trihalomethane control and suggest the need for further investigation to understand the effect of both the variability of raw water precursor levels and treatment processes on finished water TTHM levels.

Moving the chlorine application point resulted in a slight savings in chlorine feed (3.6 ug/L to 3.3 ug/L) when attempting to maintain 1.5 mg/L free

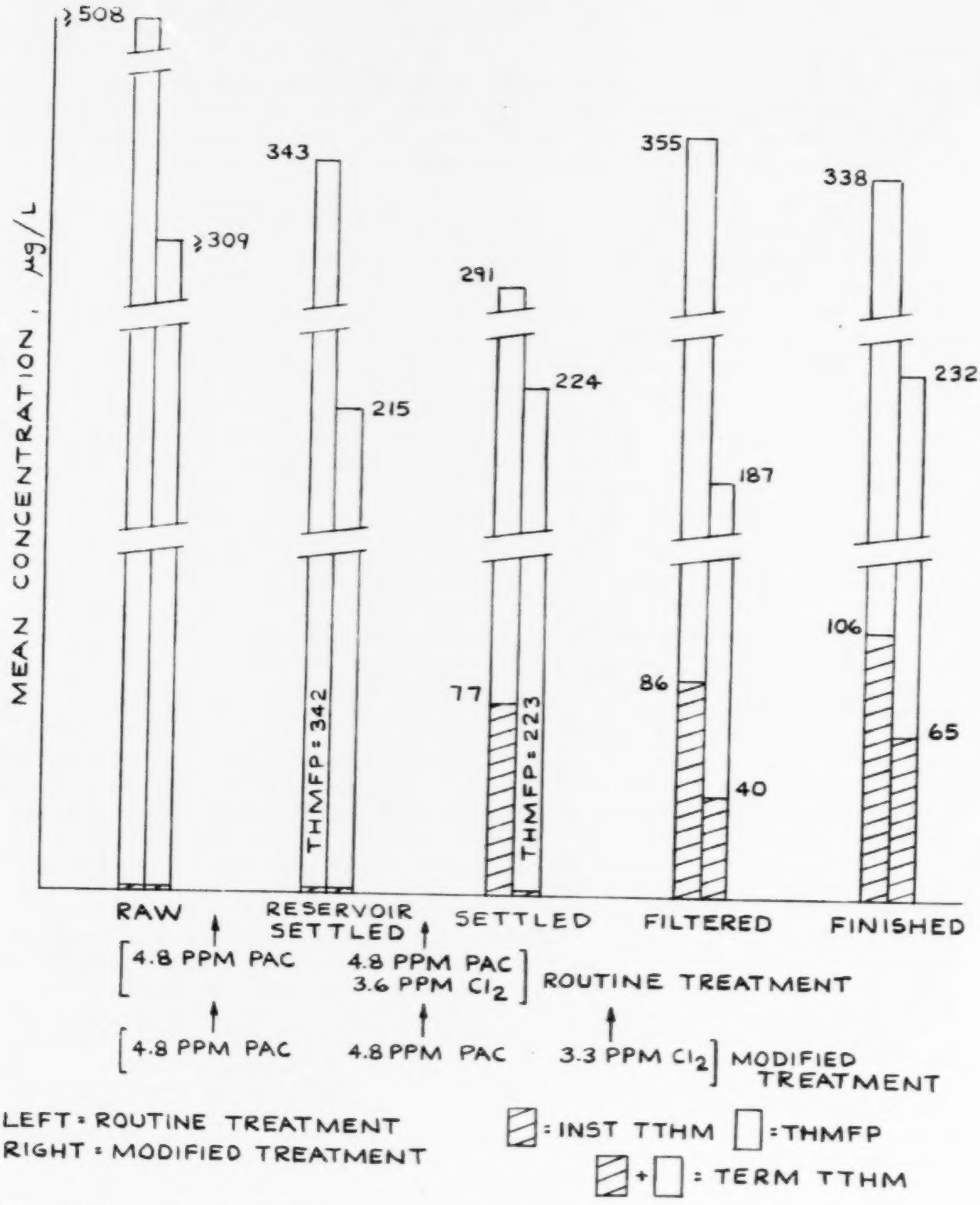


Figure 15. Trihalomethane formation (mean values), Cincinnati Water Works, 560,000 cu m/day (150 MGD), September - October 1977.

chlorine effluent from the plant.

The change in the chlorine application point had an effect on the ratio of THMs found in finished water. Brominated THMs were relatively more prevalent when chlorinating in-plant settled water. This was probably attributable to the difference in THM reaction time. Other factors include the variable nature and concentration of the precursor, the effect of unknown raw water bromide concentrations, and the uncertain role of bromine in the THM reaction. Table 10 shows individual compounds as percentages of finished water TTHM.

TABLE 10. RATIO OF INDIVIDUAL TRIHALOMETHANES TO TOTAL TRIHALOMETHANES IN THE CLEAR WELL (%), CINCINNATI WATER WORKS (INSTANTANEOUS MEAN VALUES)

	Treatment	
Compound	Routine (chlorination of gravity settled raw water)	Modified (chlorination of coagulated and settled water)
Chloroform	59%	41%
Bromodichloromethane	28%	33%
Dibromochloromethane	12%	22%
Bromoform	1%	3%
Dichloroiodomethane	1%	1%
inst TTHM[a]	106 ug/L	65 ug/L

[a] GC/Hall detector

Evaluation of Other Priority Pollutants--

For this study analyses were performed for volatile halocarbons other than THMs and for base-neutral extractable halocarbons. These compounds were found infrequently at Cincinnati and at low concentrations where precision of field data was highly variable. An evaluation of the effect of the change in chlorine application point on these compounds could not be made. These compounds will be discussed as a part of the year-long survey for Priority Pollutants in Section 7.

Bacteriological Evaluation--

Bacteriological data were evaluated during both routine and modified treatment periods and are presented in Figure 14. During both periods of the study, 48-hour, alum enhanced, reservoir settling effectively reduced total coliform densities 97%. However, an evaluation of the treatment modification involved a comparison of bacteriological data obtained from reservoir settled water with data obtained from in-plant settled water.

During routine chlorination of reservoir settled water, the mean total coliform density was reduced from a reservoir settled value of 220/100 mL to <1/100 mL in the in-plant settled water. During the modified period when chlorine was applied after in-plant settling, the mean coliform density was reduced from a reservoir settled value of 2,400/100 mL to 1,400/100 mL in the in-plant settled water; a mean density of <1/100 mL was not obtained until the in-plant settled water was chlorinated and filtered.

A similar delay in the reduction in standard plate count densities occurred with the delay in chlorination. A mean density of 5,500 bacteria/mL in the in-plant settled water without chlorination compared with a mean density of 500/mL in the in-plant settled water when chlorinated.

The delay in chlorination resulted in a parallel delay in reduction of bacterial densities until chlorine was applied. This delay resulted in no significant change in the bacterial quality of the finished water and resulted in no apparent in-plant problems.

Findings--

1. Trihalomethanes were formed during treatment after chlorine was applied.

2. Forty-eight hours of alum coagulated, reservoir settling reduced turbidity to 1.0 NTU, and also reduced precursor levels. When turbidities fell below 1.0 NTU, further reduction in precursor levels could not be observed.

3. Raw water precursor levels were significantly lower during modified treatment than during routine treatment. Because reduction in precursor levels could not be observed following reservoir settling, moving the chlorine application point from reservoir settled water to in-plant settled water resulted in chlorinating a water of lower THMFP only because precursor levels were lower during that period.

4. Significantly lower finished water trihalomethane concentrations resulted during modified treatment presumably because precursor levels were lower during that period.

5. Moving the chlorine application point resulted in some savings in chlorine feed.

6. Moving the chlorine application point reduced the in-plant THM reaction time 53% and had a significant effect on the ratio of individual THM compounds found in finished water; brominated THM concentrations were relatively higher.

7. Forty-eight hours of alum coagulated, reservoir settling reduced coliform densities 97%.

8. Moving the chlorine application point caused a delay in reduction of bacterial densities, but the bacterial quality of the finished water was not altered.

Wheeling Water Department

Routine and Modified Treatment--

Wheeling routinely chlorinated a gravity settled Ohio River water. For purposes of THM control, the chlorination point was moved to coagulated and settled water. Iron and manganese removal was accomplished by chlorine oxidation, coagulation, settling and filtration during routine treatment. When treatment was modified, the utility added permanganate as a substitute oxidant for chlorine. Water quality data representative of two weeks of routine treatment and two weeks of modified treatment are presented in Figure 16 with the treatment schematic. Figure 17 presents mean instantaneous and terminal TTHM data for both periods of study.

Evaluation of Trihalomethane Control--

The trend of individual terminal TTHM data indicated raw water precursor levels were lower during routine treatment than during modified treatment. During either study period, a statistical comparison of mean values indicated that raw water terminal TTHM and gravity settled terminal TTHM could not be differentiated; therefore, one hour of gravity settling did not reduce precursor levels. Gravity settling did not reduce turbidity levels.

During routine treatment, gravity settled and coagulated and settled mean terminal TTHM concentrations (325 ug/L and 265 ug/L, respectively) could be differentiated. Mean terminal TTHM concentrations in coagulated and settled and finished water (265 ug/L and 273 ug/L, respectively) could not be differentiated. Thus, coagulation and settling reduced precursor levels but subsequent treatment likely did not. Turbidity levels were reduced by coagulation and settling and by filtration.

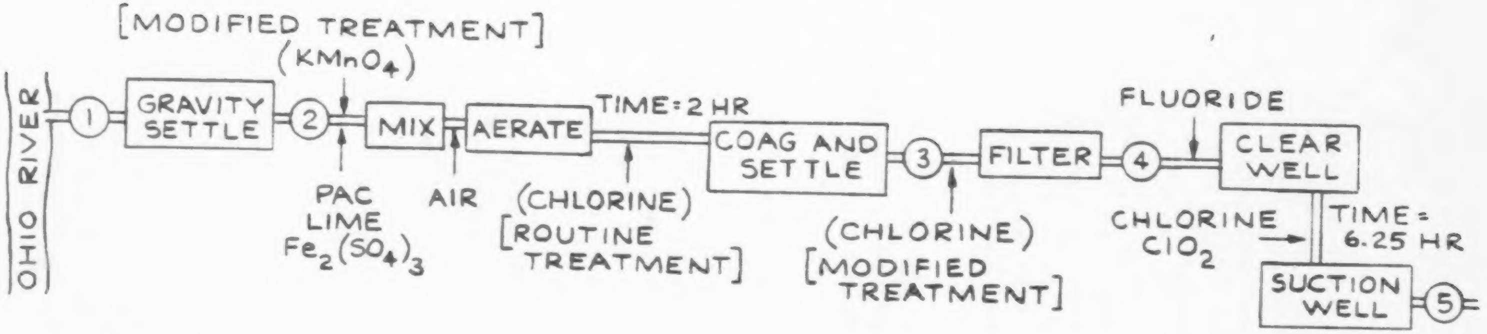
During modified treatment, gravity settled and coagulated and settled mean terminal TTHM concentrations (371 ug/L and 347 ug/L, respectively) could not be differentiated but gravity settled and finished water mean terminal TTHM concentrations (371 ug/L and 324 ug/L, respectively) were different. Thus, coagulation and settling was not as effective for precursor removal during modified treatment. The reason for this is not known. Turbidity levels were reduced by coagulation and settling and by filtration.

Because coagulation and settling was not as effective in lowering precursor levels during modified treatment and because raw water precursor levels during that period were somewhat higher, moving the application point did not result in chlorinating a water with lower THMFP (324 ug/L and 346 ug/L could not be differentiated).

However, lower instantaneous TTHM were formed in the finished water during the modification (152 ug/L compared to the modified value of 104 ug/L). This was a significant reduction in the percentage formation of TTHM from raw water precursor; 47% during routine treatment compared to 28% during the modification. Thus, moving the chlorine application point resulted in lowered finished water TTHM, not because a better quality water was chlorinated, but because the THM in-plant reaction time was decreased from $4\frac{1}{2}$ to $1\frac{1}{2}$ hours.

Although pH levels ranging from 8.9 to 9.7 were a major factor in the formation of 104 ug/L TTHM in only $1\frac{1}{2}$ hours, other factors, such as chlorine application rate, species of residual chlorine, and the nature and concentration of precursor, may have affected the reaction rate.

The change in the chlorine application point increased the percentages of the brominated THMs with a corresponding decrease in chloroform formation (Table 11). This was probably attributable to a reduction in the THM reaction time. Other factors include the variable nature and concentration of the pre-



PARAMETER	①	②	③	④	⑤
TIME, HR	0	1	5	5.5	6.5
TEMP, °C	11/12	-	-	-	-
TURB, NTU	12/9.9	10/9.6	4.2/7.0	0.3/0.5	0.4/0.5
pH	7.4/7.3	7.5/7.4	9.6/9.7	9.6/9.4	9.3/8.9
FREE Cl_2, PPM	-	-	0.4/0.1[a]	0.3/<0.1	2.1/1.6
TOTAL Cl_2, PPM	-	-	2.1/0.1[a]	1.7/2.1	3.2/2.9
TC/100 mL	7500/7700	8100/6700	<1/12	<1/<1	<1/<1
SPC/mL	-	12000/8100	9/880	1/2	<1/<1
Fe, PPM	0.8/0.7	-	0.6/0.6	-	<0.1/<0.1
Mn, PPM	0.8/0.8	-	0.4/0.3	-	0.1/0.2

LEGEND

ROUTINE TREATMENT/MODIFIED TREATMENT

○ = SAMPLE POINT

(OPTIONAL FEED)

NOTES

a = MnO_4^- INTERFERENCE

Figure 16. Treatment at Wheeling Water Department, 38,000 cu m/day (10 MGD), water quality data (mean values), November 1978.

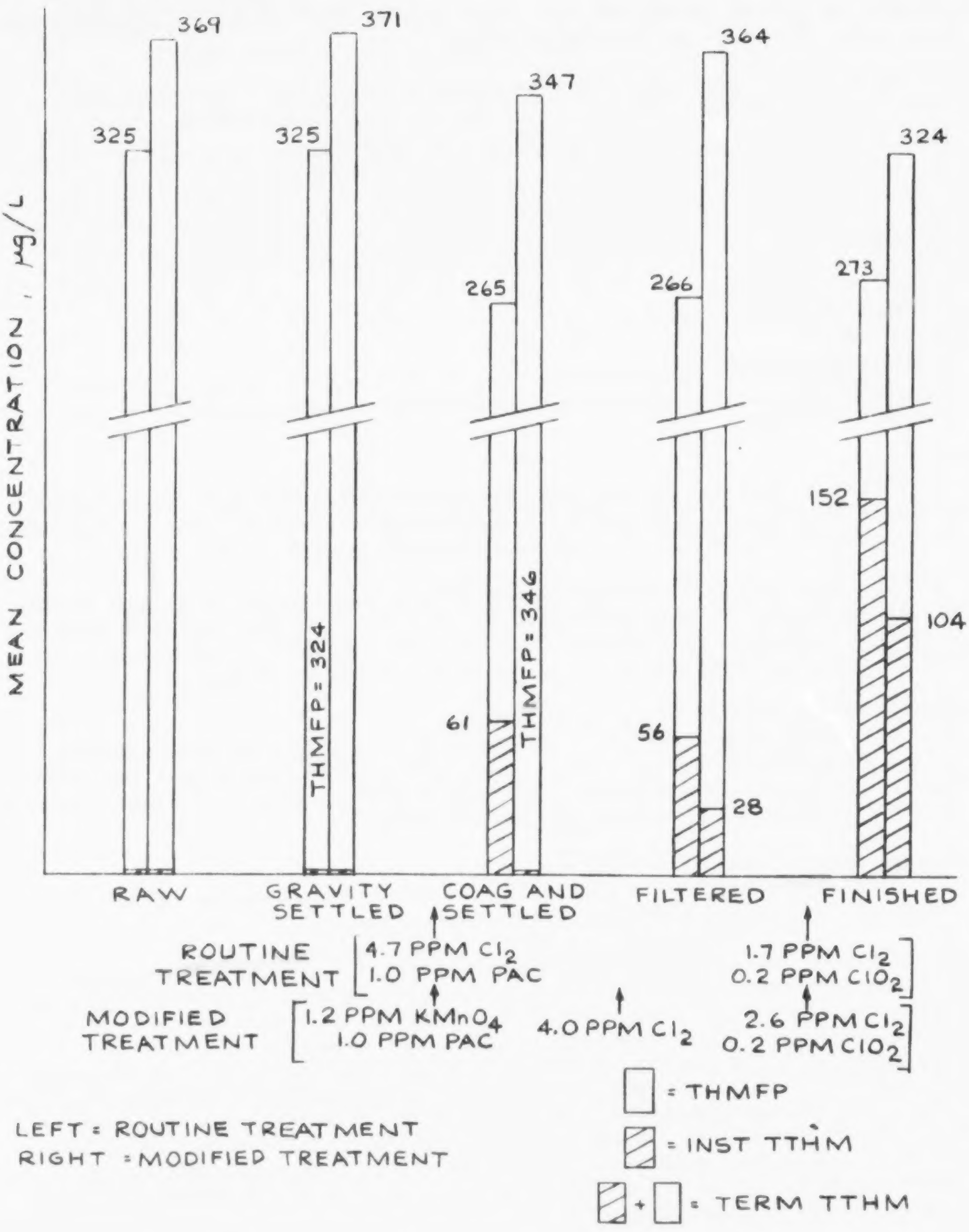


Figure 17. Trihalomethane formation (mean values), November 1978, Wheeling Water Department, 38,000 cu m/day (10 MGD).

cursor, the effect of unknown raw water bromide concentrations, and the uncertain role of bromine in the THM reaction.

TABLE 11. RATIO OF INDIVIDUAL TRIHALOMETHANES TO TOTAL TRIHALOMETHANES IN THE CLEAR WELL (%), WHEELING WATER DEPARTMENT (INSTANTANEOUS MEAN LEVELS)

	Treatment	
Compound	Routine (chlorination of gravity settled raw water)	Modified (chlorination of coagulated and settled water)
Chloroform	36%	23%
Bromodichloromethane	30%	31%
Dibromochloromethane	25%	34%
Bromoform	9%	12%
Dichloroiodomethane	1%	1%
inst TTHM[a]	152 ug/L	104 ug/L

[a] GC/Hall detector

Chlorine application was based on maintaining a 0.3 mg/L free chlorine residual onto the filters and a 2.0 mg/L finished water residual. No savings in total chlorine application resulted from the modification.

The data indicate that modified treatment with oxidation by permanganate was as effective for iron and manganese control as routine treatment with oxidation by chlorine. The effect, if any, of permanganate on precursor could not be separated from the effect of coagulation and settling.

Evaluation of Other Priority Pollutants--

This study was conducted in November of 1978 following the year-long period of monthly sampling. Annual data indicated infrequent and low level occurrence of other halocarbons. For this reason, analyses of these compounds were not performed during this THM control study.

Bacteriological Evaluation--

Bacteriological levels were evaluated during both routine and modified treatment periods and are presented in Figure 16.

The data indicate that chlorination of gravity settled raw water resulted in a complete reduction of the mean total coliform density from 8,100/100 mL in the gravity settled raw water to <1/100 mL in the coagulated and settled water. During modified treatment a significant reduction also occurred. A mean total coliform density of 6,700/100 mL in the gravity settled raw water was reduced to 12/100 mL in the coagulated and settled water without chlorination, when one hour raw water gravity settling and application of permanganate preceeded four hours of coagulation and settling. This combination of processes resulted in a significant reduction of coliform organisms; however, reduction to <1/100 mL was achieved only after chlorine was applied to the coagulated and settled water.

The delay in chlorine application during modified treatment caused a parallel delay in reduction of the standard plate count. After chlorination of gravity settled raw water, the mean standard plate count density was 9 bacteria/mL in the coagulated and settled water; after coagulation and settling without chlorination, the mean density was 880/mL. However, the mean SPC density was effectively reduced to 2 bacteria/mL after chlorination of the coagulated and settled water.

The quality of the finished water was not altered by the delay in chlorination during modified treatment. During both periods of the study, bacterial densities in the finished water complied with USEPA Interim Drinking Water Standards.

Findings--

1. Trihalomethanes were formed during treatment after chlorine was applied.

2. Raw water precursor levels were higher during modified treatment than during routine treatment.

3. One hour of gravity settling did not reduce precursor levels. Coagulation and settling were more effective for precursor removal during routine treatment than during modified treatment.

4. One hour of gravity settling did not reduce turbidity levels. Turbidity levels were reduced by coagulation, settling and filtration.

5. Moving the chlorine application point from gravity settled water to coagulated settled water did not result in chlorinating a water of lower THMFP because raw water precursor levels were higher during that period.

6. Significantly lower finished water trihalomethane concentrations resulted during modified treatment presumably because THM in-plant reaction time was reduced 67%.

7. Moving the chlorine application point and reducing the in-plant THM reaction time 67% had a significant effect on the ratio of individual THM compounds found in finished water; brominated THM concentrations were relatively higher.

8. Moving the chlorine application point caused a delay in the reduction of bacterial densities, but the bacterial quality of the finished water was not altered.

9. Coagulation, settling and permanganate application significantly reduced coliform and standard plate count densities.

THE EFFECT OF AMMONIATION ON TRIHALOMETHANE FORMATION

General

Bench scale studies have shown that combined chlorine species form trihalomethanes at a much slower rate than do free chlorine species.[5] Conversion of free chlorine to combined chlorine was a THM control evaluated full scale at the Louisville Water Company by adding ammonia as a treatment modification.

Raw, in-plant and finished waters were sampled two or three times weekly for periods of one to two weeks during both routine and modified treatment studies. For each sample day, sampling followed theoretical plug flow through the plant.

Louisville Water Company

Routine and Modified Treatment--

Chlorine was routinely applied to gravity settled raw water and to the clear well. Modified treatment evaluated the application of ammonia first to the clear well and second to the "softening" basins. Lime-soda softening was practiced during periods when raw water total hardness exceeded 140 mg/L.

During the period when routine treatment was studied, softening was practiced. During the period when ammonia was applied to the clear well, softening was practiced intermittently. Softening was off-line during the final period of study when ammonia was applied to the softening basins. The treatment schematic is presented in Figure 18. Each ammonia application point was preceeded by a chlorine application point so that chloramines were not a primary disinfectant.

Evaluation of Trihalomethane Control--

TTHM concentrations and water quality data presented in Figure 19 are representative of the period when softening was practiced and ammonia was not applied. Mean instantaneous TTHM data indicate formation of trihalomethane resulting from chlorination and enhanced by an increase in pH in the softening basins.

Significant reduction in precursor levels was not observed in-plant when mean terminal TTHM concentrations were evaluated. Evaluation of terminal level TTHM data should be made cautiously when finished water pH is lower than the pH of some in-plant waters. Waters stored for the determination of the terminal TTHM parameter were buffered to pH 8.3 to maintain finished water pH. Softened and filtered water samples collected for TTHM determinations represented several hours of instantaneous TTHM formation at pH 9.2. The rate of THM formation is pH dependent.[5] It is, therefore, possible for the terminal TTHM concentrations of softened and filtered waters to exceed the terminal TTHM concentration of settled water because of the instantaneous TTHM formed at the accelerated rate during treatment.[5] This difference in reaction rate as a function of pH was demonstrated for the utility's settled water (Figure 20).

Water quality data and TTHM concentrations representative of the period when softening was practiced intermittently and ammonia was applied to the clear well are presented in Figure 21. Mean instantaneous TTHM data indicate formation of trihalomethane resulting from chlorination and enhanced by an increase in pH in the softening basins. Statistical comparison of means indicated that softened, filtered and finished instantaneous TTHM levels could not be differentiated. Thus, there was no significant increase in THM formation during the one half hour through the filter and no significant increase in the

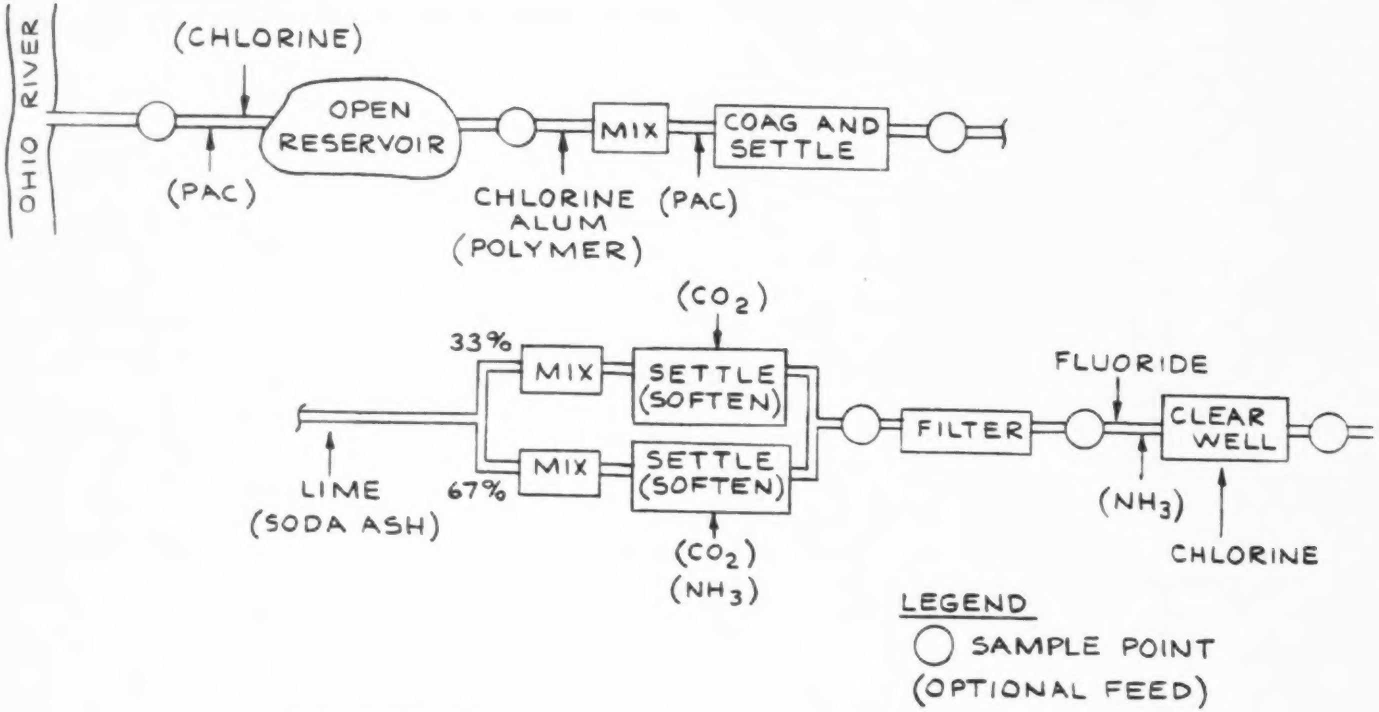
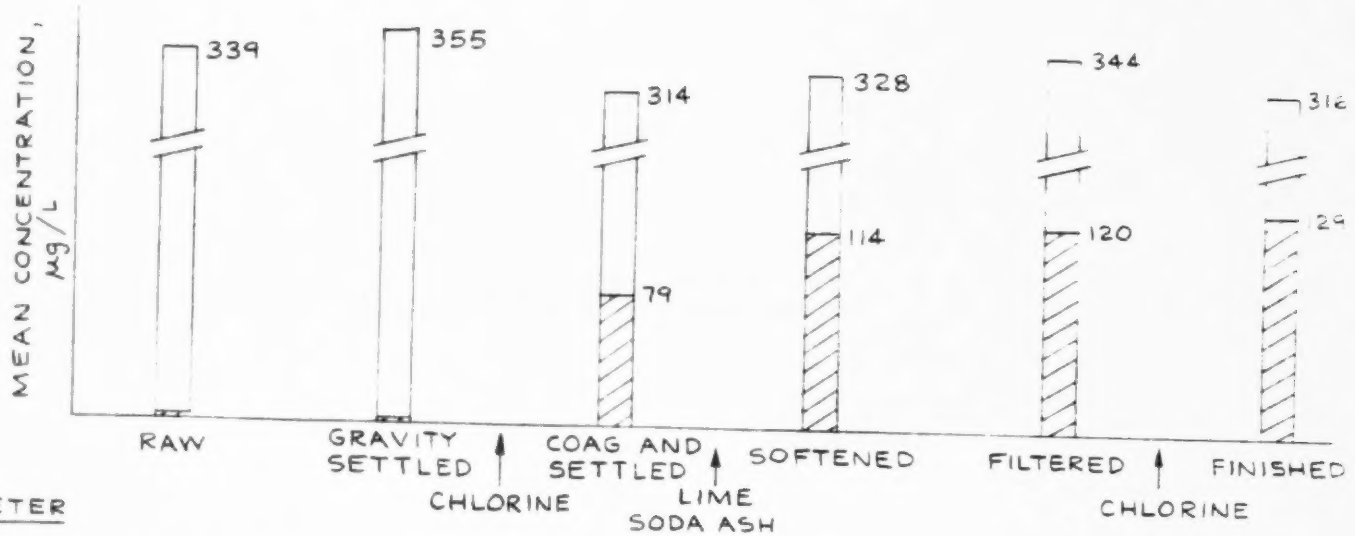


Figure 18. Treatment at Louisville Water Company, 473,000 cu m/day (125 MGD), July - October, 1977.



PARAMETER	RAW	GRAVITY SETTLED	COAG AND SETTLED	SOFTENED	FILTERED	FINISHED
TIME, HR	-8.25	0	3	5	5.5	6.25
TEMP, °C	-	-	-	-	-	29
TURB, NTU	6.5	8.2	2.1	5.0	0.2	0.2
pH	7.5	7.7	7.2	9.2	9.1	8.5
FREE Cl_2, PPM	-	-	2.5	0.6	0.3	1.8
TOTAL Cl_2, PPM	-	-	3.0	0.7	0.4	2.0
NH_3, PPM	-	-	-	-	0.1	0.1
TC /100 mL	160	110	1	<1	<1	<1
SPC /mL	-	-	<1	11	4	1

▨ = INST TTHM ☐ = THMFP

▨ + ☐ = TERM TTHM

Figure 19. Trihalomethane formation (mean values), water quality data (mean values), Louisville Water Company, 473,000 cu m/day (125 MGD), no ammoniation, softening on-line, July 1977.

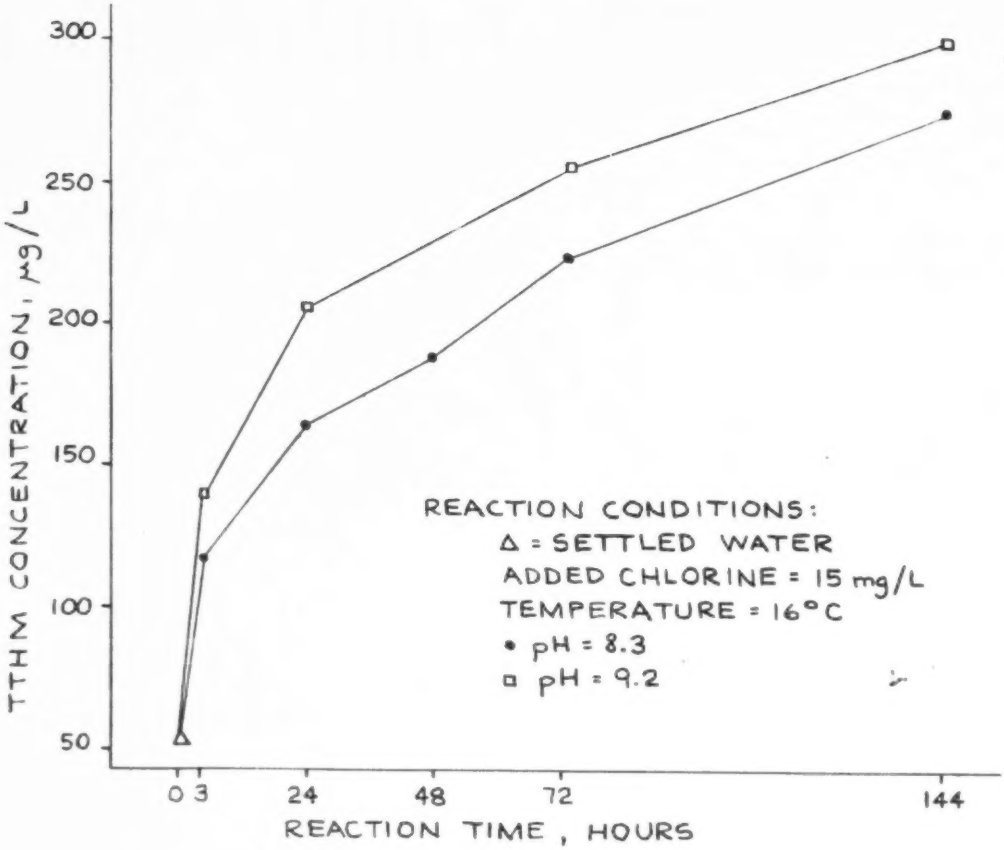
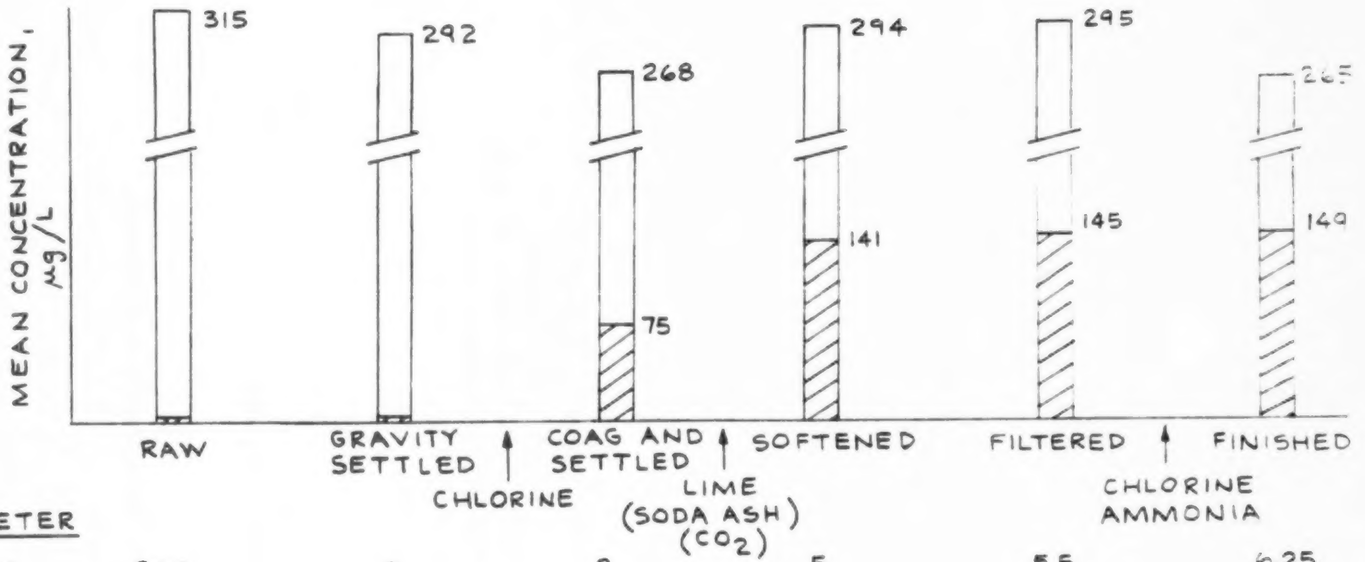


Figure 20. Effect of pH on trihalomethane formation.



PARAMETER	RAW	GRAVITY SETTLED	COAG AND SETTLED	SOFTENED	FILTERED	FINISHED
TIME, HR	-8.25	0	3	5	5.5	6.25
TEMP, °C	-	-	-	-	-	28
TURB, NTU	19	23	4.7	3.8	0.4	0.5
pH	7.3	7.5	7.0	9.2	9.1	8.2
FREE Cl_2, PPM	-	-	2.6	0.6	0.4	0.2
TOTAL Cl_2, PPM	-	-	2.8	0.7	0.5	1.4
NH_3, PPM	0.2	0.3	-	-	0.1	0.5
TC /100 mL	3200	4900	<1	<1	<1	<1
SPC /mL	-	-	<1	51	9	6

LEGEND

(FEED ON-LINE/OFF LINE)

▨ = INST TTHM ☐ = THMFP

▨ + ☐ = TERM TTHM

Figure 21. Trihalomethane formation (mean values), water quality data (mean values), Louisville Water Company, 473,000 cu m/day (125 MGD), clear well ammoniation, softening on/off-line, August 1977.

clear well after ammonia had been applied.

The trend of terminal TTHM data represented by mean concentrations in Figure 21 indicated reduction in precursor between raw and finished water.

Data representative of the period when softening was not practiced and ammonia was applied to the softening basins are presented in Figure 22.

A problem at the contract laboratory resulted in a considerable loss of project samples collected during October of 1977--the time of this last phase of ammonia application. Consequently, THM data presented in Figure 22 represent 60%-80% of the samples collected.

Detention time in the open reservoir was longer during this period of "softening" basin ammoniation than during previous periods (22 hours compared to eight hours), because part of the reservoir had earlier been off-line.

The reservoirs were chlorinated intermittently during this period for algal control resulting in 9.6 ug/L mean instantaneous TTHM. Chlorination of settling basins increased TTHM to 65 ug/L. Sufficient ammonia was applied to two-thirds of the "softening" basins to carry an ammonia residual to the distribution system. Because one-third of the basins were not ammoniated, the THM reaction proceeded until these waters were mixed. Mean "softened" water TTHM therefore reached 84 ug/L. On the non-ammoniated side, the pH was 7.9; on the ammoniated side, it was 9.3. No further THM formation was observed across the filter. A statistical comparison indicated that a mean of 83 ug/L TTHM in the filtered water and a mean of 94 ug/L TTHM in the finished water could not be differentiated. Thus, the TTHM formation proceeded in the plant as a result of chlorination. However, little further increase in TTHM resulted in waters subsequently treated with ammonia.

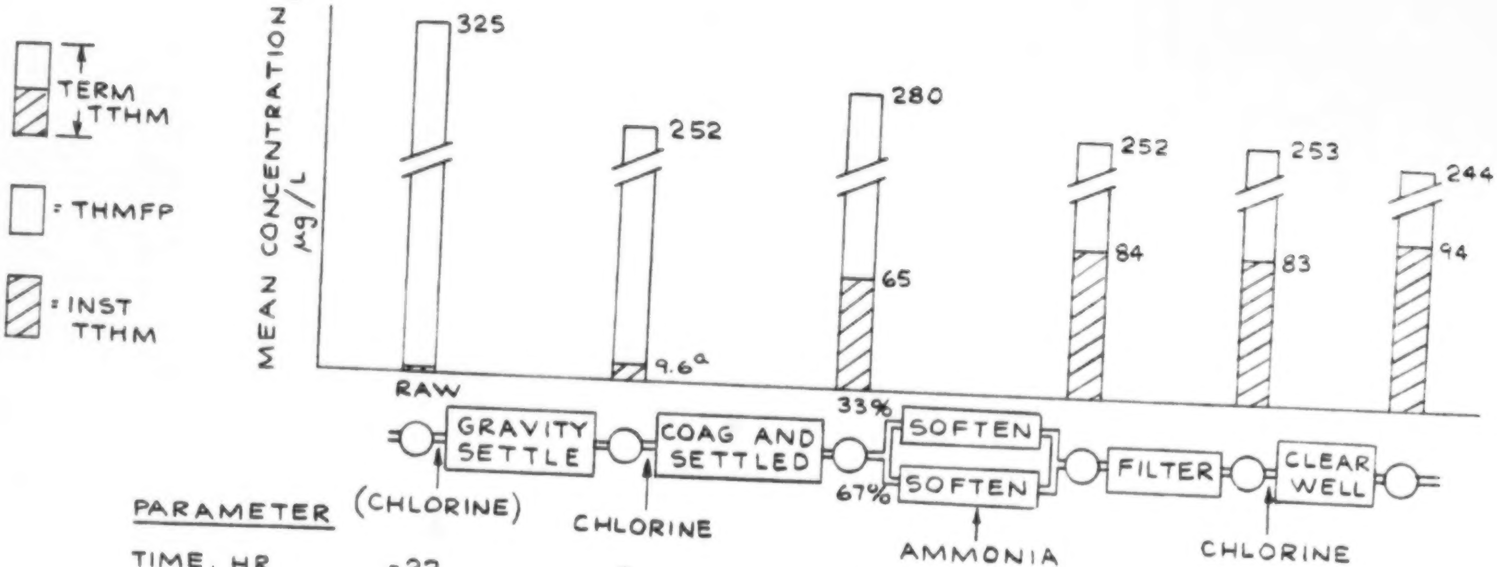
Comparisons of mean terminal TTHM concentrations (Figure 22) indicated that raw and gravity settled mean concentrations were different, that gravity settled and coagulated settled mean concentrations could not be differentiated, and that coagulated settled and finished mean concentrations could not be differentiated. Thus, 22 hours of gravity settling reduced precursor levels but subsequent treatment probably did not.

During the three periods of study, significant precursor level reduction was observed only during 22-hour gravity settling. Turbidity reduction, however, occurred during coagulated settling. not during gravity settling. The relationship between turbidity levels and precursor levels suggested by other utility studies was not supported during this study.

Ammoniation had no significant effect on the ratio of individual THM compounds in the finished water. Table 12 shows individual compounds as percentages of instantaneous TTHM.

Evaluation of Other Priority Pollutants--

For this study analyses were performed for volatile halocarbons other than THMs and for base-neutral extractable halocarbons. These compounds were found infrequently at Louisville and typically at low concentrations where



PARAMETER						
TIME, HR	-22	0	3	5	5.5	6.25
TEMP, °C	-	-	-	-	-	16
TURB, NTU	15	18	4.6	2.5	0.3	0.3
pH	7.5	7.6	7.2	b	9.0	8.6
FREE Cl_2, PPM	-	-	1.7	c	0.1	<0.1
TOTAL Cl_2, PPM	-	-	1.9	d	1.5	1.9
NH_3, PPM	0.1	0.1	<0.1	e	1.0	0.6
TC /100 mL	4000	1100	<1	<1	<1	<1
SPC /mL	-	-	2	3	2	1

NOTES

a RANGE: <1 TO 23
b NH_3 SIDE = 9.3, NON-NH_3 SIDE = 7.9
c NH_3 SIDE = <0.1, NON-NH_3 SIDE = 1.2

NOTES

d NH_3 SIDE = 1.8, NON-NH_3 SIDE = 1.3
e NH_3 SIDE = 1.7, NON-NH_3 SIDE = 0.1

Figure 22. Trihalomethane formation (mean values), water quality data (mean values), Louisville Water Company, 473,000 cu m/day (125 MGD), settled water ammoniation, softening off-line, October 1977.

TABLE 12. RATIO OF INDIVIDUAL TRIHALOMETHANES TO TOTAL TRIHALOMETHANES IN THE CLEAR WELL (%), LOUISVILLE WATER COMPANY (INSTANTANEOUS MEAN VALUES)

Compound	Treatment: Routine	Treatment: Modified (clear well ammoniation)	Treatment: Modified (ammoniation of softening basins)
Chloroform	53%	57%	69%
Bromodichloromethane	30%	28%	24%
Dibromochloromethane	17%	14%	6%
Bromoform	1%	1%	1%
Dichloroiodomethane	1%	1%	1%
inst TTHM[a]	129 ug/L	149 ug/L	94 ug/L

[a] GC/Hall detector

precision of field data was highly variable. An evaluation of the effect of ammoniation on these compounds could not be made. These compounds will be discussed as a part of the year-long survey for Priority Pollutants in Section 7.

Bacteriological Evaluation--

A comparison of the bacteriological conditions during the three periods of study was made. During each period, the application of chlorine to gravity settled raw water effected a complete reduction in both total coliform and standard plate count densities. Densities remained low in all subsequent in-plant samples. With clear well chlorination, with clear well ammoniation and chlorination, and with ammoniation of softening basins and clear well chlorination, the bacteriological quality of the finished water was satisfactory.

Findings--

1. Trihalomethanes were formed during treatment after chlorine was applied.

2. When ammonia was applied to in-plant waters sufficient to convert free chlorine to combined chlorine, little or no further trihalomethane formation resulted.

3. Precursor levels were reduced by 22-hour gravity settling. Turbidity levels were not reduced by gravity settling but were reduced by coagulation and settling.

4. The bacteriological quality of the finished water was satisfactory when ammoniation followed three hours of free chlorine disinfection.

THE EFFECT OF CHLORINE DIOXIDE ON TRIHALOMETHANE FORMATION

General

An examination of the THM reaction

$$Cl_2 + \text{precursor} + Br^- + I^- \rightarrow \text{THMs}$$

indicates that if the chlorination practice were discontinued, the reaction would not proceed. This would be an acceptable means of trihalomethane control only if an equally effective disinfectant were substituted. USEPA has demonstrated on the pilot scale and bench scale that chlorine dioxide (ClO_2) reacts with precursor to form little or no trihalomethanes and reacts to lower precursor concentration.[6] Chlorine dioxide was studied as a THM control at the Western Pennsylvania Water Company.

Western Pennsylvania Water Company

Routine and Modified Treatment--

At the company's Hays Mine plant, routine treatment included chlorination of Monongahela River water. For THM control, chlorine dioxide was substituted for chlorine as the raw water disinfectant. The treatment schematic for this utility is presented in Figure 23. Raw water flow was split inside the plant and each stream was treated separately. For this study, only one side of the plant was sampled and modified. Two and one-half year old Filtrasorb 400 granular activated carbon (GAC) served as a filter/adsorber in the plant.

The utility's raw, in-plant and finished waters were sampled two to four times weekly during routine and modified treatment. For each sample day, the sample collection schedule followed the time of travel of a theoretical plug of raw water through the plant to the clear well.

During any full scale study, significant changes in raw water quality could necessitate treatment modification and/or affect the quality of in-plant waters. Such changes affected THM control studies at this utility when unusually high precursor and ammonia concentrations occurred. The following discussions address four THM study periods. While they represent routine (raw water chlorination) and modified (raw water chlorine dioxide disinfection) treatment, they are probably not representative of typical THM formation and precursor control at the utility.

Raw Water Chlorination--

Evaluation of Trihalomethane Control--Chlorine was applied to raw water at 2.6 mg/L for two weeks in July 1978. Water quality data and instantaneous TTHM concentrations are presented in Figure 25. Raw water ammonia concentrations were low (0.1 mg/L mean) during this period. Trihalomethane formation resulted from the application of chlorine to the raw water and further formation resulted from chlorine application to the clear well.

Precursor levels were found to be unusually high during this July 1978 period. The utility's raw water was sampled for determination of terminal TTHM once a month between July 1977 and May 1978. It was also sampled frequently in September and October 1978. Raw water terminal TTHM concentrations ranging from 200 ug/L to 250 ug/L were typical. During this July 1978 period, however, raw water terminal TTHM concentrations exceed 1,200 ug/L. These were the highest levels detected during the project, but the reason for these unusually high precursor levels is not known. These data are presented in Table 13. The ratio of terminal level chloroform relative to terminal level brominated THMs was unusually high. The concentrations of terminal level

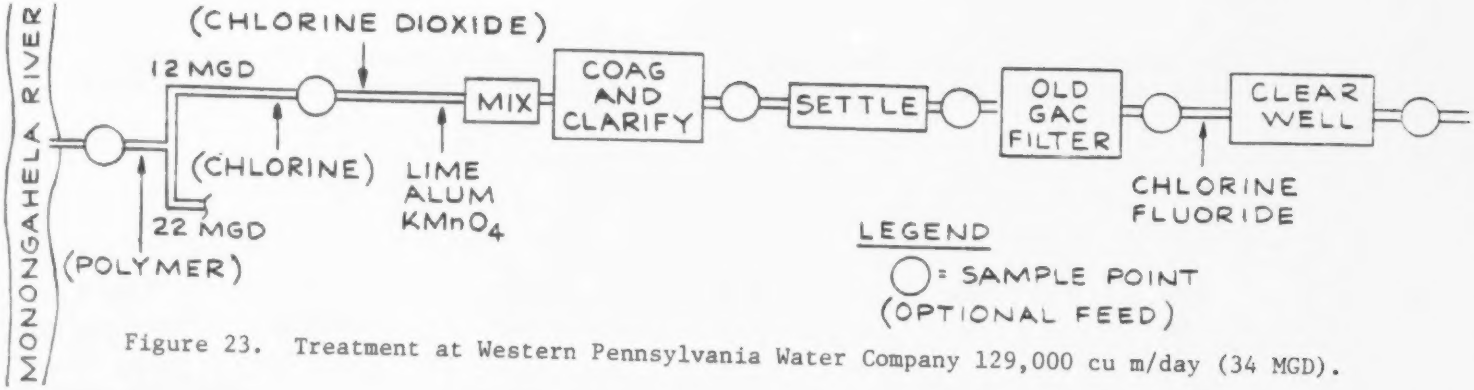


Figure 23. Treatment at Western Pennsylvania Water Company 129,000 cu m/day (34 MGD).

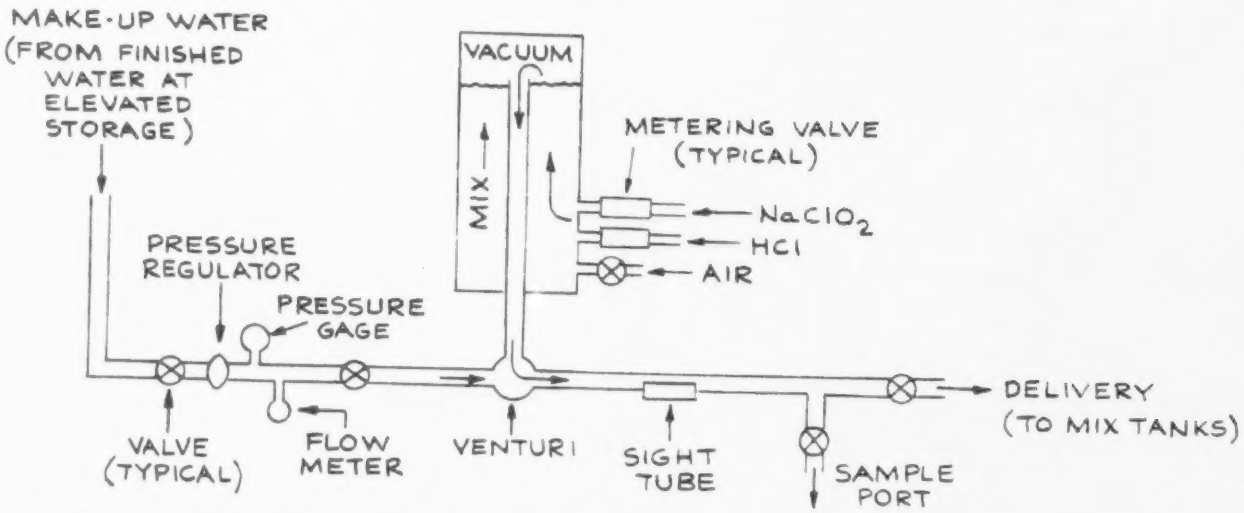
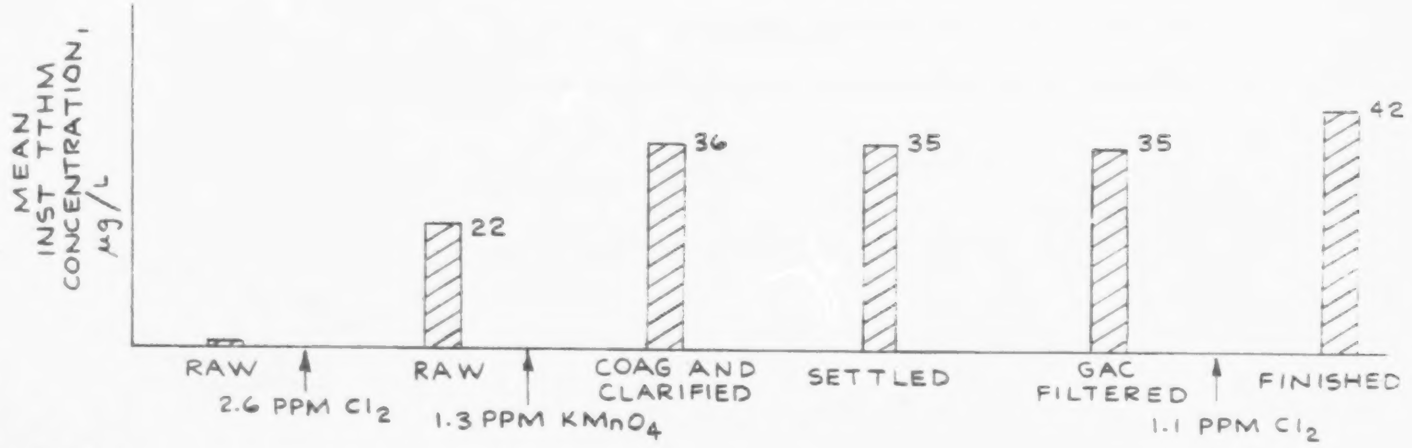


Figure 24. ORENCO* chlorine dioxide generator, Western Pennsylvania Water Company.

*Rio Linda Chemical Co., Rio Linda, CA



PARAMETER						
TIME, HR	0	0.5	3.75	12.5	13.5	14.75
TEMP, °C	-	-	-	-	-	22
TURB, NTU	51	38	5.7	8.5	0.6	0.2
pH	7.2	7.1	7.3	7.1	7.2	7.1
FREE Cl_2, PPM	-	0.4	<0.1	<0.1	<0.1	0.6
TOTAL Cl_2, PPM	-	0.8	0.4	0.3	0.2	0.8
NH_3, PPM	0.1	-	<0.1	-	-	<0.1
TC /100 mL	21000	4	1	1	8	<1
SPC /mL	-	490	200	50	150	3

Figure 25. Trihalomethane formation (mean values), water quality data (mean values), Western Pennsylvania Water Company, 45,000 cu m/day (12 MGD), raw water chlorination, July 1978.

brominated THMs were similar to those observed at other times at the utility, indicating that high terminal TTHM concentrations were attributable to unusually high raw water precursor levels and not to unusually high river bromide concentrations.

TABLE 13. TERMINAL TTHM CONCENTRATION
WESTERN PENNSYLVANIA WATER COMPANY

Water		Concentration,[a] ug/L (Mean Values)			
		July 5-7, 1978		July 10-14, 1978	
Raw TTHM		450		1200	
Finished TTHM -	$CHCl_3$	171 -	150	1060 -	1030
	$CHBrCl_2$		16		19
	$CHBr_2Cl$		5.2		5.7
	$CHBr_3$		0.4		1.6

[a] GC/Hall detector

Bacteriological Evaluation--Bacteriological data, presented in Figure 25, indicate that a significant reduction in total coliform and standard plate count densities resulted from raw water chlorination. However, a slight increase in both TC and SPC densities occurred through the GAC filter/adsorber. Chlorine application at the clear well further reduced bacterial densities. Total coliform and standard plate count densities in the finished water complied with the 1975 USEPA Interim Drinking Water Standards.

Raw Water Application of Chlorine Dioxide--

Chlorine Dioxide Generation--Chlorine dioxide (ClO_2) was evaluated as a modification to treatment in September 1978. Problems with the control of ClO_2 generation in July 1978 prevented evaluation at that time. Alterations to the generator by the manufacturer resulted in the configuration shown in Figure 24.

Chlorine dioxide was generated by reacting sodium chlorite with hydrochloric acid thereby allowing the utility to take raw water chlorinators off line. An analytical procedure was employed to measure ClO_2, chlorite, free chlorine and total chlorine in generator effluent samples and in in-plant waters.[12] The generator was found to produce chlorine dioxide and little or no free chlorine. The generator's yield of ClO_2 (mg/L ClO_2 produced per mg/L chlorite consumed) was approximately 80%. The yield of free chlorine was 5% or less. The generator may have produced no free chlorine. Dilution factors and the sensitivity of the analytical procedure below 0.1 mg/L did not allow accurate free chlorine determination. Unreacted chlorite was not found in the generator's effluent. The application rate of ClO_2 to raw water was 1.5 mg/L and the accompanying free chlorine application rate was less than 0.1 mg/L. The ClO_2 application rate did not exceed 1.5 mg/L for economic reasons. USEPA has proposed a 1.0 mg/L limit.[16]

Evaluation of Trihalomethane Control--Water quality data and TTHM concentrations representing this treatment period are given in Figure 26. As a result of treating raw water with 1.5 mg/L chlorine dioxide and less than 0.1 mg/L free chlorine, low instantaneous TTHM concentrations were found in settled water. The increase in TTHM through the filter/adsorber was likely a result of desorption of TTHM from the three-year-old GAC. Post-chlorination further increased TTHM concentration in the clear well. Thus, generated in the manner described, chlorine dioxide formed little trihalomethane; TTHM found in the finished water was attributable to clear well chlorination and to desorption from GAC.

Raw water ammonia concentrations were unusually high (1.2 mg/L mean) and variable (0.5 mg/L to 1.9 mg/L) during this period. Chlorine dioxide does not react with ammonia.[17] With chlorine dioxide generated as described, little or no free chlorine was applied to the raw water. Therefore, it is assumed that these ammonia concentrations had no effect on instantaneous TTHM formation. High ammonia concentrations did interfere, however, in maintaining a free chlorine residual in samples for the determination of terminal level TTHM concentrations. As a result, the terminal TTHM concentrations presented in Figure 26 represent only 50%-75% of the samples collected for the determination of this parameter. These data suggest little, if any, precursor removal by treatment because mean concentrations of 206 ug/L and 181 ug/L could not be differentiated. The effect of ClO_2, and settling, and of permanganate on precursor levels could not be separated.

Chloro-species Evaluation--Data presented in Figure 26 indicate that 1.5 mg/L ClO_2 applied to raw water was consumed in several hours. One end product was chlorite; its concentration decreased through the plant (0.9 mg/L in clarified water to less than 0.1 mg/L in finished water), with most of the decrease occurring across the GAC filter/adsorber (0.6 mg/L to 0.1 mg/L). No attempt was made to measure other chlorine dioxide end products.

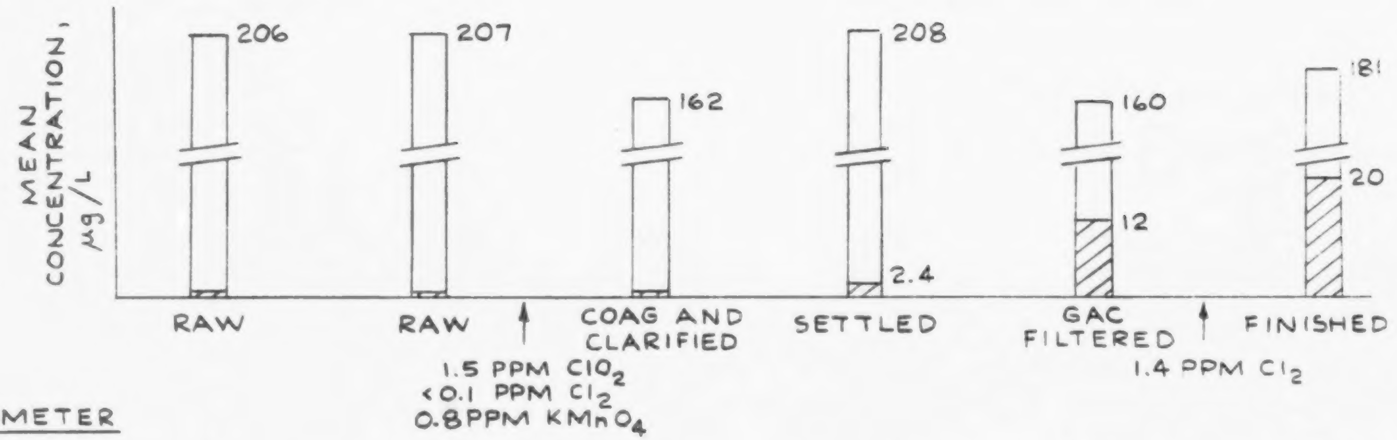
Bacteriological Evaluation--Bacteriological data presented in Figure 26 indicate that 1.5 mg/L ClO_2 application was not so effective a raw water disinfectant as 2.6 mg/L chlorine. During raw water chlorination, mean total coliform and standard plate count densities in the GAC filter/adsorber influent were 1/100 mL and 50/mL, respectively (Figure 25). During ClO_2 application to raw water, however, mean bacterial densities in the GAC influent were 43/100 mL for total coliforms and 7,100/mL for standard plate count organisms. With chlorine disinfection at the clear well during this period of study, finished water bacterial densities were satisfactory.

Raw Water Application of Chlorine and Chlorine Dioxide with High Background Ammonia Levels--

Because 1.5 mg/L ClO_2 was not an acceptable control for filter/adsorber bacterial densities, a treatment modification was evaluated in which the ClO_2 feed was reduced to 1.0 mg/L and raw water chlorinators were brought on-line at 1.2 mg/L. Data for this period are presented in Figure 27.

Raw water ammonia concentrations during this period remained unusually high (0.6 mg/L mean). Ammonia concentrations measured in-plant fluctuated widely (up to 4.0 mg/L).

Evaluation of Trihalomethane Control--TTHM formation was dependent on the concentration of ammonia present. Chlorine applied at 1.2 mg/L was rapidly converted to the combined chlorine species--which drive the THM reaction at a very slow rate.[5] Therefore, low instantaneous TTHM concentrations were found in settled water. The TTHM increase through the GAC filter/adsorber was



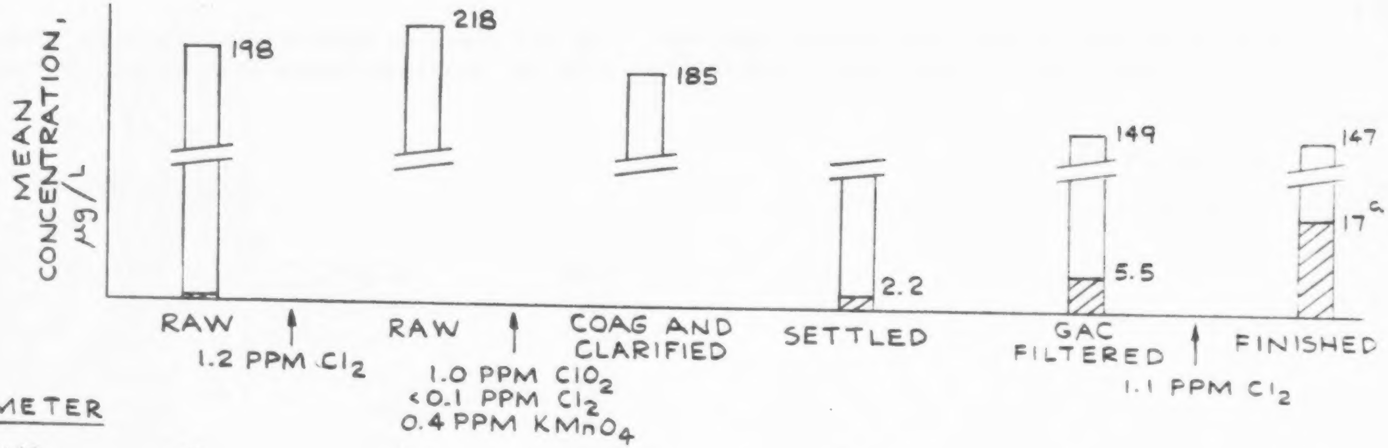
PARAMETER	RAW	RAW	COAG AND CLARIFIED	SETTLED	GAC FILTERED	FINISHED
TIME, HR	0	0.5	3.75	12.5	13.5	14.75
TEMP, °C	-	-	-	-	-	27
TURB, NTU	6.8	5.2	6.3	2.3	0.3	0.2
pH	7.1	7.1	7.5	7.4	6.9	6.8
FREE Cl_2, PPM	-	ND	<0.1	<0.1	0.1	0.4
ClO_2, PPM	-	ND	<0.1	<0.1	<0.1	<0.1
ClO_2^-, PPM	-	<0.1	<0.9	0.6	0.1	<0.1
NH_3, PPM	1.2	-	1.2	-	<0.1	<0.1
TC /100 mL	14000	4200	100	43	44	<1
SPC /mL	-	29000	4700	7100	850	1

ND = NOT DETECTED

▨ = INST TTHM ☐ = THMFP

▨ + ☐ = TERM TTHM

Figure 26. Trihalomethane formation (mean values), water quality data (mean values), Western Pennsylvania Water Company, 45,000 cu m/day (12 MGD), chlorine dioxide application, September 1978.



PARAMETER	RAW	RAW	COAG AND CLARIFIED	SETTLED	GAC FILTERED	FINISHED
TIME, HR	0	0.5	3.75	12.5	13.5	14.75
TEMP, °C	-	-	-	-	-	25
TURB, NTU	12	7.9	6.2	2.7	0.1	0.1
pH	7.1	7.1	7.2	7.7	7.0	6.9
FREE Cl_2, PPM	-	<0.1	ND	<0.1	ND	0.1[b]
TOTAL Cl_2, PPM	-	0.8	1.1	0.9	<0.1	0.7
ClO_2, PPM	-	ND	<0.1	ND	ND	<0.1
ClO_2^-, PPM	-	-	0.7	0.5	<0.1	0.1
NH_3, PPM	0.6	0.6	2.5	3.1	1.0	1.0[a]
TC/100mL	14000	2100	<1	<1	2	<1
SPC/mL	-	5900	66	33	440	8

NOTES

a RANGE = 5.2 TO 50
b RANGE = ND TO 0.45
c RANGE = 1.6 TO <0.1
ND = NOT DETECTED

▨ = INST TTHM ☐ = THMFP
▨ + ☐ = TERM TTHM

Figure 27. Trihalomethane formation (mean values, water quality data (mean values), Western Pennsylvania Water Company, 45,000 cu m/day (12 MGD), application of chlorine and ClO_2 with background ammonia, September 1978.

likely attributable to desorption. With post-chlorination, further formation of TTHM varied inversely with the concentration of ammonia in the clear well. When clear well ammonia was less than 0.1 mg/L, free chlorine was 0.45 mg/L and finished water TTHM reached 50 ug/L. When clear well ammonia was 1.6 ug/L, no free chlorine was detected and finished water TTHM reached only 5.2 ug/L--a level that could not be differentiated from the filter/adsorber effluent TTHM concentration. Thus with high levels of background ammonia present, THM formation was essentially halted. Because of the presence of ammonia, the combined effects of ClO_2 and chlorine on TTHM formation could not be evaluated.

High ammonia concentrations interfered with free chlorine added to samples for the determination of terminal level TTHM concentrations. Therefore, terminal TTHM concentrations presented in Figure 27 represent 0% to 75% of the samples collected for the determination of this parameter. Comparisons of mean terminal TTHM concentrations indicated reduction of precursor level between the raw water and filtered water sample points. The effect of ClO_2 on precursor could not be separated from the effect of coagulation and settling.

Chloro-species Evaluation--Demand for ClO_2 consumed the 1.0 mg/L applied to raw water and chlorite was found as an end product. GAC filtration/adsorption accounted for most of the removal of chlorite during treatment (0.7 mg/L after clarifiaction, 0.5 mg/L after settling, and less than 0.1 mg/L after filtration/adsorption).

Bacteriological Evaluation--Bacteriological data presented in Figure 27 indicate that pre-disinfection with chlorine and ClO_2 was satisfactory for control of bacterial densities in the GAC influent. Chlorine applied to the raw water was rapidly converted to combined chlorine forms because of high ammonia levels in the raw water during this time period. A complete reduction in bacterial densities did not occur immediately upon chlorination. However, densities in the GAC influent were satisfactory with <1/100 mL for total coliform bacteria and 33/mL for standard plate count bacteria. Again, bacterial densities increased through the GAC filter/adsorber. GAC effluent densities were 2/100 mL and 440/mL for the total coliform and standard plate count bacteria, respectively. With application of chlorine at the clear well, finished water bacterial densities were satisfactory.

Raw Water Chlorination with High Background Ammonia Levels--

Chlorination of raw water was again evaluated in October 1978, when raw water ammonia concentrations were unusually high (1.5 mg/L mean). TTHM concentrations and water quality data for this period are presented in Figure 28.

Evaluation of Trihalomethane Control--The applied chlorine (2.2 mg/L) was rapidly converted to the combined chlorine species. With little or no free chlorine present, only low concentrations of instantaneous TTHM were detected in settled water. The slight increase in TTHM through the GAC filter/adsorber was probably attributable to desorption. Further formation of TTHM in the clear well resulted from post-chlorination only if ammonia concentrations were low. With 0.1 mg/L ammonia in the clear well, the free chlorine concentration was 0.6 mg/L resulting in 43 ug/L TTHM. With 1.5 mg/L ammonia in the clear well, no free chlorine was detected and only 7.1 ug/L TTHM resulted in the finished water--a level that could not be differentiated from the filter/adsorber effluent. Thus, with sufficient levels of background ammonia present to convert free chlorine to combined chlorine, only low concentrations of instantaneous TTHM resulted.

Comparisons of mean terminal TTHM data indicated reduction in precursor levels by coagulation, clarification and settling. These data are based on 67% of the samples collected for determination of this parameter. High ammonia concentrations interfered with free chlorine added to samples for the determination of terminal TTHM.

Bacterial Evaluation--Bacteriological data presented in Figure 28 indicate that predisinfection with 2.2 mg/L chlorine was satisfactory during this period when raw water ammonia levels were in excess of 1 mg/L. An increase in standard plate count densities again occurred through the GAC filter/adsorber. However, with chlorine application at the clear well, the total coliform and standard plate count densities were satisfactory in the finished water.

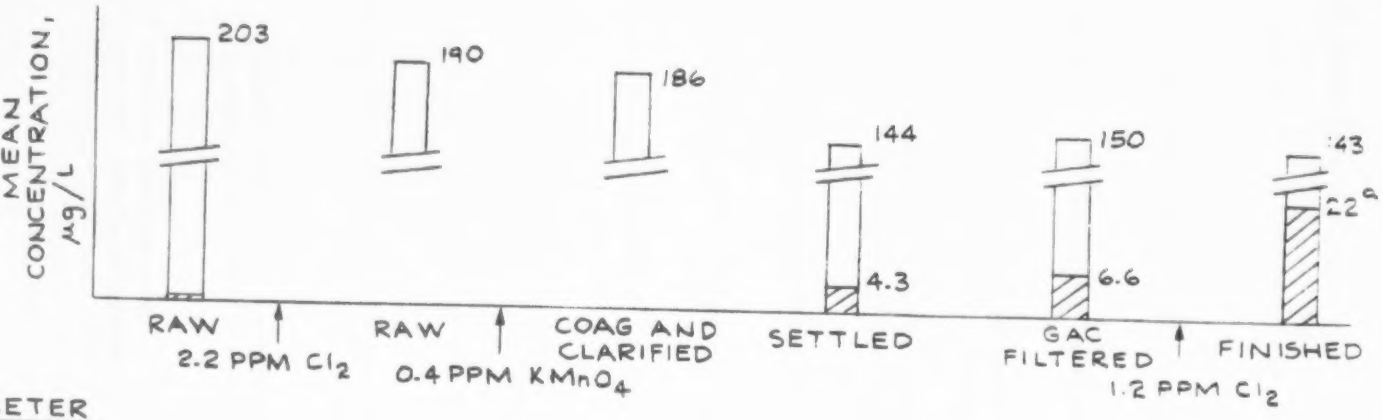
Ratio of THM Compounds--

Data presented in Table 14 indicate differences in the ratio of individual THMs found in finished water during the four study periods. Relatively higher concentrations of $CHCl_3$ were found when free chlorine residuals were carried through the entire treatment process (raw water chlorination in July). Relatively higher concentrations of brominated THMs were found when free chlorine residuals were observed only in the clear well (treatment with ClO_2 and/or sufficient ammonia to convert pre-chlorine disinfectant to combined species in September and October). Other than the difference in reaction time with free chlorine, possible causative factors include the variable nature and concentration of the precursor from July to October, the effect of unknown raw water bromide concentrations, and the uncertain role of bromine in forming THMs.

TABLE 14. RATIO OF INDIVIDUAL TRIHALOMETHANES TO TOTAL TRIHALOMETHANES IN THE CLEAR WELL (%), WESTERN PENNSYLVANIA WATER COMPANY (INSTANTANEOUS MEAN VALUES)

	Pre-Treatment			
Compound	Routine (raw water chlorination, no background ammonia) (July 1978)	Modified (ClO_2 to raw water) (Sep 1978)	Modified (ClO_2 and chlorine to raw water, background ammonia) (Sep 1978)	Routine (raw water chlorination, background ammonia) (Oct 1978)
$CHCl_3$	71%	26%	23%	20%
$CHBrCl_2$	20%	28%	33%	32%
$CHBr_2Cl$	8%	36%	36%	39%
$CHBr_3$	1%	10%	8%	9%
$CHICl_2$	1%	1%	1%	1%
inst TTHM[a]	42 ug/L	20 ug/L	17 ug/L	22 ug/L

[a] GC/Hall detector



PARAMETER	RAW	RAW	COAG AND CLARIFIED	SETTLED	GAC FILTERED	FINISHED
TIME, HR	0	0.5	3.75	12.5	13.5	14.75
TEMP, °C	-	-	-	-	-	23
TURB, NTU	10	8.6	4.1	2.1	0.3	0.2
pH	7.1	7.2	8.1	7.4	7.0	6.9
FREE Cl_2, PPM	-	<0.1	ND	<0.1	ND	0.3[b]
TOTAL Cl_2, PPM	-	1.8	1.4	1.6	<0.1	0.9
NH_3, PPM	1.5	-	1.5	-	-	0.4[c]
TC /100mL	25000	21	<1	8	3	<1
SPC /mL	-	120	28	28	200	22

NOTES

a RANGE = 7.1 TO 43
b RANGE = ND TO 0.6
c RANGE = 1.5 TO <0.1
ND = NOT DETECTED

▨ = INST TTHM ☐ = THMFP
▨ + ☐ = TERM TTHM

Figure 28. Trihalomethane formation (mean values), water quality data (mean values), Western Pennsylvania Water Company, 45,000 cu m/day (12 MGD), raw water chlorination with background ammonia, September - October 1978.

Evaluation of Other Priority Pollutants--

These studies were conducted from July through October 1978 following the year-long period of monthly sampling. Annual data indicated infrequent and low level occurrence of other halocarbons; therefore, analyses of these compounds were not performed during these studies.

Findings--

1. Trihalomethanes were formed during treatment after chlorine was applied.

2. Little or no trihalomethanes were formed when only chlorine dioxide was applied to raw water.

3. With background ammonia concentrations sufficient to convert free chlorine to combined chlorine, little or no trihalomethane formation resulted.

4. When applied to raw water with sufficient demand, chlorine dioxide was consumed. An end product measured was chlorite. In three hours on a mg/L basis, 60%-70% of the applied ClO_2 went to chlorite.

5. Settling and GAC filtration/adsorption decreased chlorite concentrations to less than 0.1 mg/L in the finished water.

6. When applied to raw water, 1.5 mg/L ClO_2 was not so effective a disinfectant as 2.6 mg/L chlorine.

7. When applied to raw water, the combination of 1.0 mg/L ClO_2 and 1.2 mg/L chlorine was as effective a disinfectant as 2.6 mg/L chlorine.

8. With temperatures above 22°C, total coliform and standard plate count densities increased through GAC filtration/adsorption.

9. The bacterial quality of the finished water was satisfactory with chlorine post-disinfection.

10. Chlorine dioxide generation by chlorite and hydrochloric acid had an 80% yield (mg/L ClO_2 produced per mg/L ClO_2^- consumed). The yield of free chlorine was less than 5%.

11. Ammonia and precursor conditions on the Monongahela River varied considerably. The effects of routine and modified treatment on precursor levels could not be evaluated.

12. Two-and-one-half year old GACs receiving chlorinated and settled water in the filtration/adsorption mode in beds designed for sand filtration were exhausted for the removal of $CHCl_3$, $CHBrCl_2$, $CHBr_2Cl$, $CHBr_3$ and instantaneous TTHM. With a significant decrease in influent instantaneous TTHM concentrations, instantaneous TTHM was likely desorbed from the GAC.

THE EFFECT OF GRANULAR ACTIVATED CARBON ADSORPTION/FILTRATION ON TRIHALOMETHANE CONTROL

General

An adsorber can control trihalomethanes in two ways. An examination of the THM reaction

$$Cl_2 + \text{precursor} + Br^- + I^- \rightarrow \text{THMs}$$

indicates that a reduction in THM formation would result if precursor levels were reduced or if THMs were formed and subsequently removed. Granular activated carbon (GAC) has been shown to adsorb both precursor and trihalomethanes in pilot scale operation.[6] This means of control was examined full scale at two project utilities: the Huntington Water Corporation and the Beaver Falls Authority. These two studies investigated the adsorptive capacity of virgin GAC in the filtration/adsorption mode over time.

At each utility, raw, finished, GAC influent and GAC effluent waters were sampled one or more times weekly to define exhaustion of GAC for the removal of THMFP and instantaneous TTHM and to evaluate GAC filtration/adsorption for a period of time following exhaustion. For each sample day, waters were sampled following a theoretical plug from raw water through the plant to the clear well.

GAC Evaluation

GAC evaluation for this project was based on exhaustion. Exhaustion was determined by a point in time when effluent concentrations of a compound or group of compounds equaled or first exceeded influent concentrations. Appendix C indicates that variability of a reported instantaneous TTHM concentration can approach ± 20%. This variability was considered in determining when influent and effluent concentrations were likely equal. In a hypothetical case, apparent exhaustion of a GAC for the removal of TTHM was defined at 10 weeks when the effluent concentration of 20 ug/L exceeded the influent concentration of 17 ug/L. If, however, at nine weeks, the influent concentration was 31 ug/L and the effluent level was 26 ug/L, exhaustion may have occurred. Given ± 20% variability of the data, these concentrations could have been 25 ug/L and 31 ug/L, respectively, indicating earlier exhaustion. Thus, trend should also be considered when defining exhaustion. The data following the point of apparent exhaustion should indicate influent and effluent concentrations within 20% of each other or should indicate effluent concentrations generally exceeding influent concentrations. The exhaustion of GAC, as discussed in this report, is consistent with such trends.

Breakthrough was determined by a point in time when a compound was first detected in the GAC effluent.

Huntington Water Corporation

Background--

At Huntington a virgin GAC bed was evaluated for adsorption of influent instantaneous trihalomethanes and influent unreacted precursor (THMFP). Westvaco's WVW 14x40 GAC was evaluated. The selection of GAC was based on its history of effective taste and odor control at the utility. The virgin GAC replaced taste and odor exhausted GAC. It was operated in the filtration/adsorption mode in a bed originally designed for sand filtration. No previous pilot scale studies had been conducted to determine optimum selection of GAC or bed depth for organics control.

The bed was placed with 76 cm (30 inches) of GAC on top of 30 cm (12 inches) of sand and gravel. After placement, the bed was backwashed several times to remove fine particulates. When the bed was placed in operation, it received chlorinated, coagulated and settled water. Treatment is illustrated in Figure 29. Backwashing frequency was based on head loss and effluent turbidity levels. The bed was backwashed 16 times the first week and 14 times the second week and an average of eight times per week thereafter. Hydraulic data provided by the utility demonstrated a mean loading rate of 6.1 m/hr (2.6 gpm/ft^2) and a mean empty bed contact time (EBCT) of 7.2 minutes. Water quality data for the utility are given in Table 15.

The virgin GAC bed represented only 8% of the plant capacity. Periodically, influent and effluent waters for older WVW 14x40 GAC beds were sampled to evaluate performance after long periods of time in operation.

Trihalomethane Adsorption by Virgin GAC--

Figure 30 illustrates removal of TTHM by virgin GAC after varying lengths of time in operation. Breakthrough of THMFP and instantaneous TTHM was observed during the first week as both were detected in the bed's effluent. By the fourth week of operation, the percent removal of THMFP and instantaneous TTHM by the GAC bed was decreasing with time. After 22 weeks of operation, influent and effluent concentrations could not be differentiated, indicating that exhaustion had occurred on or before that time.

Figure 31 is a plot of the removal of instantaneous TTHM by GAC adsorption for the first 45 weeks of operation of the virgin bed showing that the GAC was exhausted for the removal of instantaneous TTHM at seven to eight weeks of operation. (Prior to that time, influent concentrations exceeded effluent concentrations by at least 20%. Following that time, effluent concentrations exceeded influent concentrations, or influent and effluent concentrations were within 20% of one another, and thus could not be differentiated.) The GAC was exhausted for the removal of THMFP at seven to ten weeks of operation as illustrated by Figure 31.

The adsorption of individual instantaneous THMs by virgin GAC is plotted in Figure 32. These data indicate that the GAC was exhausted for the removal of chloroform at seven to eight weeks of operation. Exhaustion for the removal of bromodichloromethane and dibromochloromethane occurred at 11 to 14 weeks of operation.

Data presented in Table 16 indicate that the virgin GAC was not exhausted for bromoform removal at 12 weeks of operation. Beyond that time, influent and effluent concentrations were low and could not be differentiated. Appendix C, Figure C-9, indicates that the precision of field data for instantan-

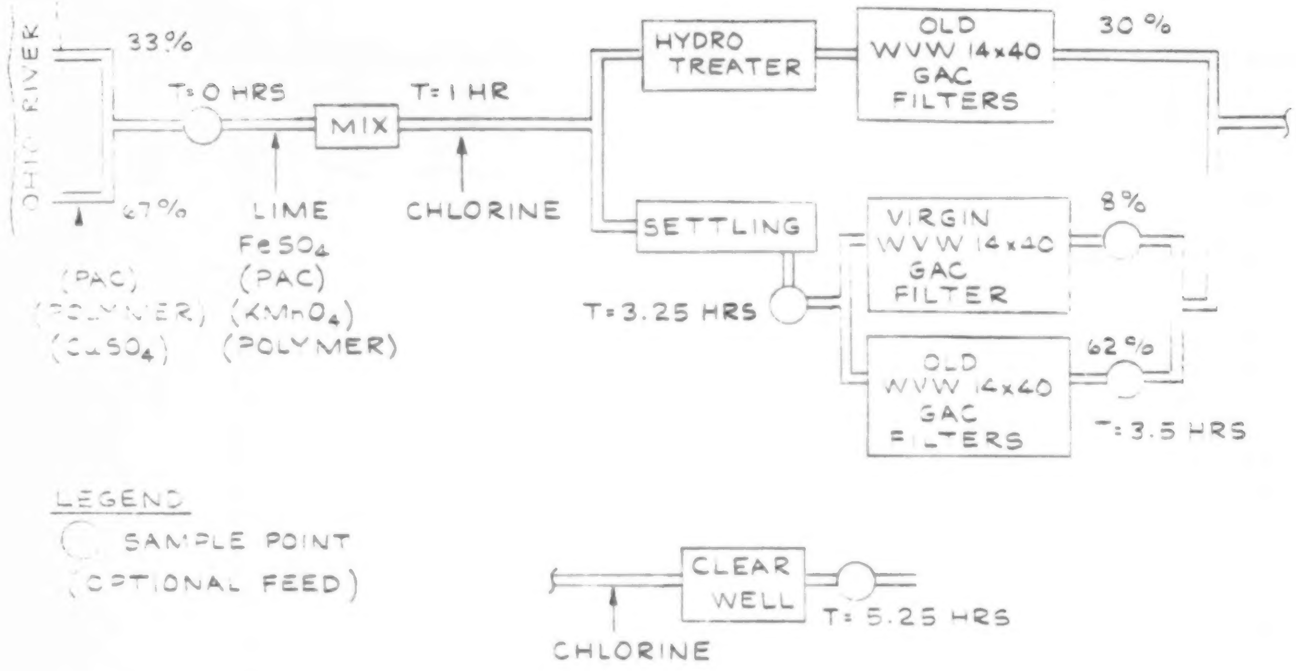


Figure 29. Treatment at Huntington Water Corporation, 64,000 cu m/day (17 MGD), July 1977-March 1978.

TABLE 15. WATER QUALITY DATA (MEAN VALUES) HUNTINGTON WATER CORPORATION JULY 1977–MARCH 1978

Week of Virgin GAC Operation	Raw Water Mean pH = 7.5			GAC Influent (Settled) Mean pH = 8.9					Virgin GAC Effluent Mean pH = 8.7				
					Chlorine[a]					Chlorine[a]			
	Temp, °C	Turb[b]	TC[c]	Turb[b]	Free	Total	TC[c]	SPC[d]	Turb[b]	Free	Total	TC[c]	SPC[d]
1	27	14	1,600	2.0	0.8	1.4	<1	4	0.2	ND	ND	<1	100
2	28	21	1,200	4.6	0.3	0.4	<1	52	1.5	ND	TR	<1	53
3	28	26	910	4.9	1.8	3.7	<1	42	1.4	0.1	0.3	6	12
4	28	13	870	4.4	0.5	0.7	<1	7	1.7	TR	0.3	8	41
5	28	15	1,500	6.5	0.6	0.9	<1	18	1.8	0.4	0.6	5	18
6	27	80	3,000	5.8	0.5	0.8	<1	28	1.1	0.1	0.2	<1	13
7	27	37	5,300	3.8	0.4	0.7	<1	17	0.5	TR	0.1	<1	3
8	27	34	2,300	5.9	0.3	0.6	<1	22	1.5	0.2	0.4	2	25
9	27	17	1,400	3.3	0.5	0.7	<1	24	0.3	TR	0.2	2	46
10	27	18	970	4.6	0.5	0.7	<1	26	3.2	TR	0.2	<1	140
11	26	25	1,100	7.9	0.4	0.6	<1	28	1.7	TR	0.2	<1	23
12	24	24	1,700	4.4	0.5	0.7	<1	28	0.4	TR	TR	1	12
13	19	47	3,100	8.7	0.5	0.8	<1	31	0.4	TR	0.2	<1	30
14	19	98	4,300	4.3	0.5	0.9	<1	--	0.4	0.1	0.4	<1	--
15	14	34	3,900	16	0.5	0.7	<1	34	0.4	--	--	<1	2
16	15	22	2,600	9.1	0.5	0.9	<1	39	1.0	TR	0.5	<1	10
17	15	18	2,800	10	0.4	0.9	<1	18	0.5	TR	0.6	<1	2
20	11	42	3,900	5.5	0.6	0.8	<1	200	0.7	0.3	0.4	<1	4
22	8	240	1,400	9.8	0.2	0.3	<1	55	12	0.2	0.4	<1	11
23	5	160	26,000	8.0	0.5	0.6	<1	36	0.8	0.2	0.3	<1	3
25	3	24	2,800	7.0	ND	0.7	<1	30	0.5	ND	0.5	<1	<1
27	2	30	5,900	9.0	0.9	1.1	<1	--	0.2	0.3	0.5	<1	--
31	2	34	610	14	0.3	0.9	<1	--	0.3	0.4	0.8	<1	--

[a] Chlorine, mg/L
[b] Turbidity, NTU
[c] Total coliform/100 mL
[d] Standard plate count/mL

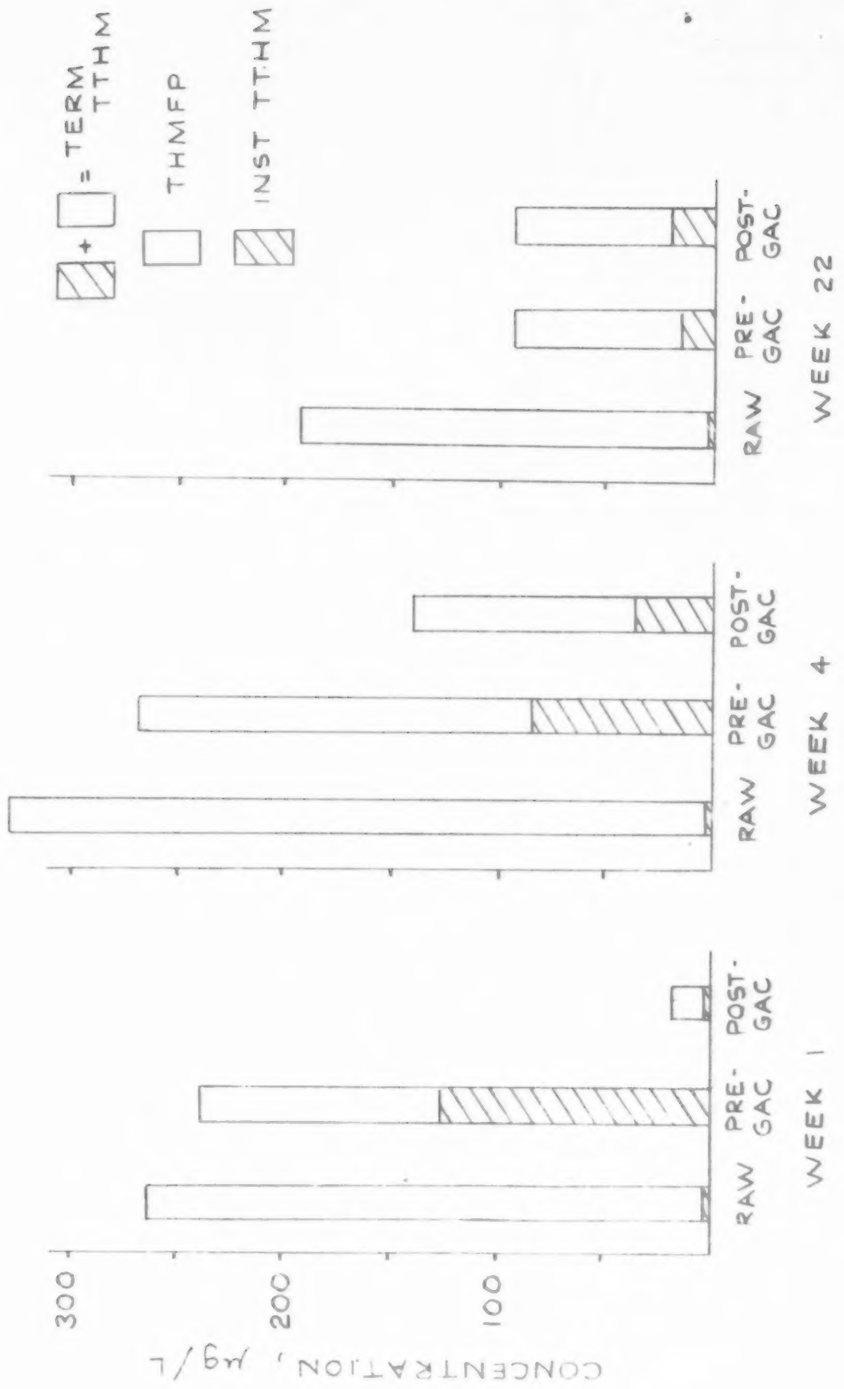


Figure 30. Trihalomethane formation, Huntington Water Corporation.

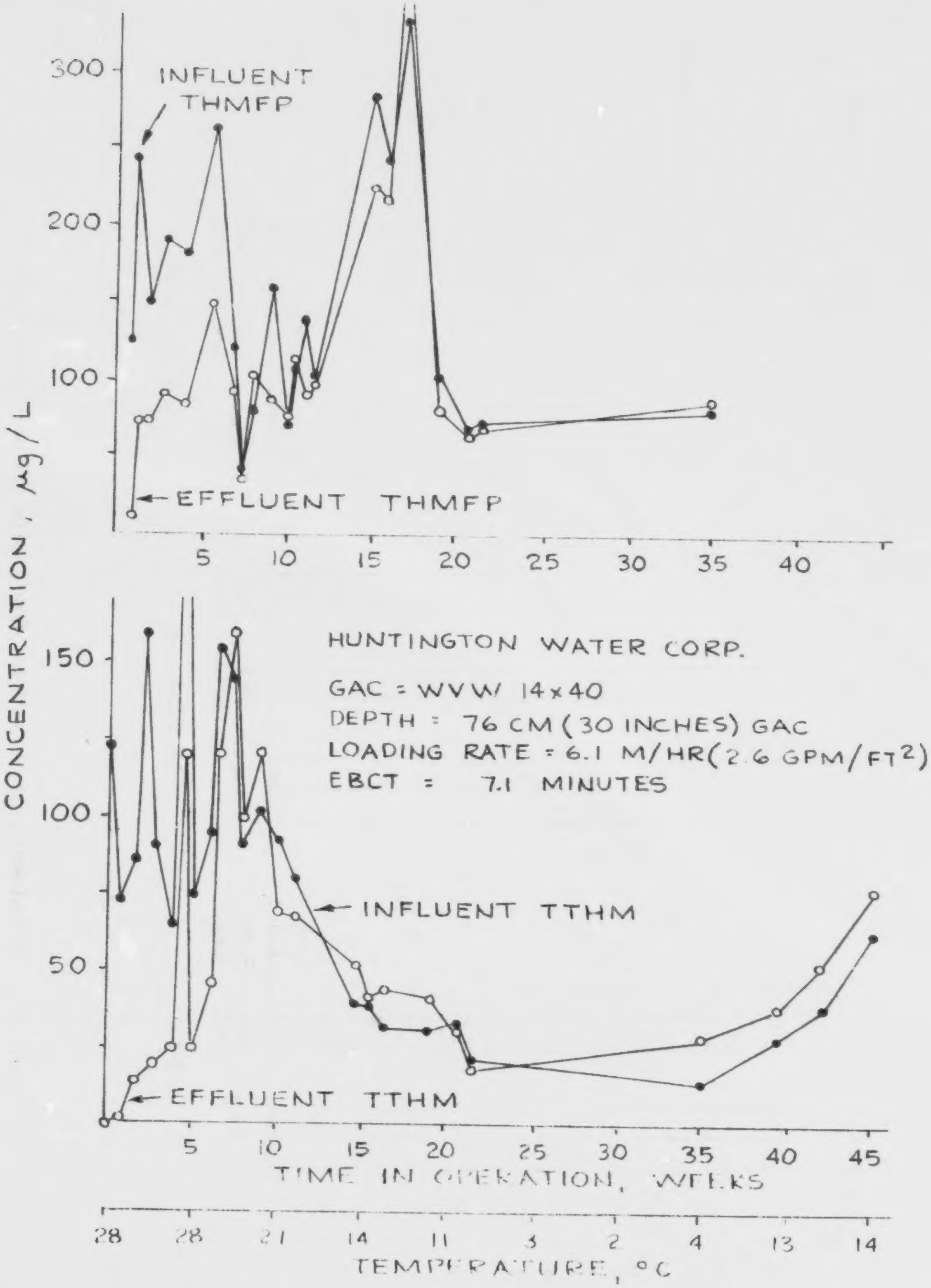


Figure 31. Trihalomethane removal by granular activated carbon.

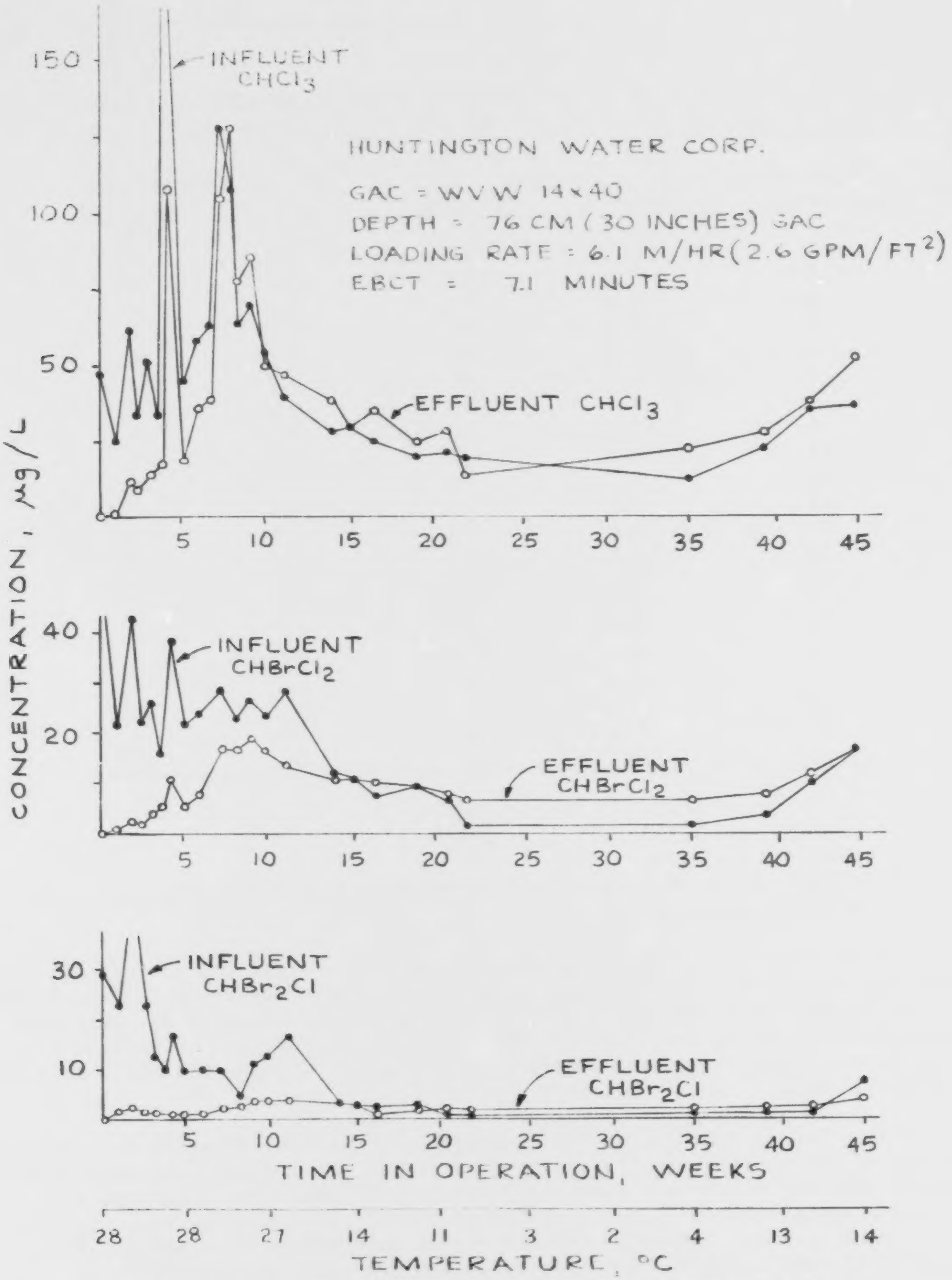


Figure 32. Trihalomethane removal by granular activated carbon.

eous bromoform could be ± 15% for concentrations above 1.0 ug/L, ± 40% near 0.5 ug/L, and ± 100% below 0.2 ug/L.

TABLE 16. REMOVAL OF TRIHALOMETHANES BY GRANULAR ACTIVATED CARBON[a]
HUNTINGTON WATER CORPORATION, JULY 1977-MAY 1978

	Concentration,[b] ug/L			
Week of	Bromoform		Dichloroiodomethane	
Operation	Influent	Effluent	Influent	Effluent
1	1.6	ND	<0.1	ND
2	4.4	<0.1	0.1	ND
3	1.2	<0.1	0.3	ND
4	0.3	ND	0.2	<0.1
5	0.2	<0.1	0.2	<0.1
6	0.2	ND	0.4	<0.1
7	0.1	ND	0.7	<0.1
8	0.5	<0.1	0.6	<0.1
9	0.6	0.1	0.4	ND
10	1.5	0.2	0.2	<0.1
11	1.6	0.2	0.2	<0.1
12	1.9	0.2	0.1	0.1
15	<0.1	0.1	<0.1	<0.1
16	0.1	<0.1	<0.1	<0.1
17	0.1	0.1	0.1	<0.1
19	0.2	<0.1	<0.1	ND
21	ND	ND	ND	<0.1
22	ND	<0.1	ND	<0.1
35	ND	ND	ND	<0.1
39	ND	<0.1	0.1	<0.1
42	ND	ND	<0.1	<0.1
45	0.5	0.2	0.2	<0.1

[a]GAC = WVW 14x40
Bed depth = 76 cm (30 inches) GAC
Loading rate = 6.1 m/hr (2.6 gpm/ft^2)
EBCT = 7.2 minutes
[b]GC/Hall detector, approximate lower detection level = 0.1 ug/L
ND = not detected

Data presented in Table 16 indicate that the virgin GAC was not exhausted for the removal of dichloroiodomethane at 11 weeks of operation. Beyond that time, influent and effluent concentrations were low and could not be differentiated. Appendix C, Table C-6 indicates that the precision of field data for instantaneous dichloroiodomethane could be ± 40% below 0.2 ug/L and ± 100% below 0.1 ug/L.

The data in Table 16 do not show that the GAC was exhausted for the removal of bromoform or dichloroiodomethane after the 11th or 12th week of operation because, after that time, influent and effluent concentrations were too low for interpretation. During later operation, when temperatures and influent concentrations increased, further adsorption may have occurred. Figure 31 indicates that influent TTHM concentrations generally varied with temperature.

Trihalomethane Adsorption by Older GAC--

Periodically older WVW 14x40 GAC bed effluent waters were sampled. These beds were of identical geometry and similar hydraulics and received the same water as the virgin GAC bed.

One bed was sampled during its 9th, 11th, 13th and 14th months of operation. It was found to be exhausted for the removal of THMFP, chloroform, bromodichloromethane and dibromochloromethane and instantaneous TTHM, however, it was not exhausted for the removal of bromoform after 11 months of operation. At 13-14 months of operation, with lower temperatures, influent bromoform concentrations were low and could not be differentiated from effluent concentrations. These data are presented in Table 17.

Another bed was sampled during its 27th, 28th, 29th, 31st and 32nd month of operation. It was found to be exhausted for the removal of THMPF, chloroform, bromodichloromethane, dibromochloromethane, instantaneous TTHM and, possibly, bromoform. The precision of field data for bromoform (Appendix C, Figure C-9) indicates that the influent and effluent bromoform concentrations cannot be differentiated. These bromoform data are presented in Table 17.

Adsorption of Priority Pollutants and Other Compounds by Virgin GAC--

Analyses were performed for compounds other than trihalomethanes in GAC influent and effluent waters to determine their adsorption by virgin GAC when present. Purgeable halocarbons and base-neutral extractable halocarbons were detected infrequently, and, when detected, their concentrations were low and in ranges where precision of the field data indicates that influent and effluent concentrations could not be differentiated, i.e., the compounds were typically detected at or below 0.2 ug/L. Until more sensitive analytical procedures are employed, the adsorptive capacity of GAC for these compounds at low concentrations cannot be evaluated. There were exceptions, however.

Carbon Tetrachloride--Carbon tetrachloride occurred frequently in Huntington's raw and GAC influent waters. Table 18 presents influent and effluent data for the virgin GAC. Appendix C, Figure C-8, indicates that the precision of carbon tetrachloride data below 0.2 ug/L may be ± 100%; therefore, influent and effluent concentrations below 0.2 ug/L were too low to be differentiated. The data in Table 18 indicate adsorption occurred during weeks 5, 10 and 12, for example, but influent and effluent concentrations could not be differentiated during weeks 14 or 42. These data indicate that virgin GAC was an effective barrier when higher influent concentrations occurred (week 10); that in the first two months of operation, it adsorbed the influent load (breakthrough was not observed until week 9); but that after several months of operation, it was not acting as a barrier to the routine influent loading. During weeks 16 and 42 the compound was detected in the effluent at concentrations that could not be differentiated from influent concentrations. This does not imply that exhaustion had occurred after several months of operation or that the GAC would not act as an effective barrier to a higher influent load at a later time.

Chlorobenzene--Chlorobenzene was detected infrequently in GAC influent waters. However, when detected, data indicate that chlorobenzene was adsorbed. During the 6th week of operation, the influent concentration was

TABLE 17. REMOVAL OF BROMOFORM BY GRANULAR ACTIVATED CARBON[a], HUNTINGTON WATER CORPORATION

	Bromoform Concentration, ug/L[b]								
	Virgin GAC Placed July 1977[c]			GAC Placed October 1976			GAC Placed April 1975		
Raw Water Temp (°C)	Month of Operation	Influent	Effluent	Month of Operation	Influent	Effluent	Month of Operation	Influent	Effluent
28	1	1.9	0.1	9	2.0	0.4	27	2.0	1.0
28	1 1/2	0.2	0.1	9 1/2	4.4	2.0	27 1/2	4.4	4.6
27	2	0.3	0.1				28	0.1	0.3
26	3	1.4	0.2	11	1.9	1.1	29	1.8	1.4
17	4	0.1	0.1						
9	5	0.1	0.1	13	0.2	0.2	31	0.2	0.4
5	6	ND	0.1	14	ND	0.1	32	ND	ND

[a] GAC = WVW 14x40
Bed depth = 76 cm (30 inches) GAC
Loading rate = 6.1 m/hr (2.6 gpm/ft^2) for virgin bed
EBCT = 7.2 minutes for virgin bed

[b] GC/Hall detector, approximate lower detection level = 0.1 ug/L

[c] Data taken from Table 16.

ND = not detected

TABLE 18. REMOVAL OF CARBON TETRACHLORIDE BY VIRGIN GRANULAR ACTIVATED CARBON[a] HUNTINGTON WATER CORPORATION, JULY 1977-MAY 1978

Week of Operation	Concentration,[b] ug/L Influent	Concentration,[b] ug/L Effluent	Week of Operation	Concentration,[b] ug/L Influent	Concentration,[b] ug/L Effluent
1	<0.1[c]	ND	12	0.5	0.1
2	ND	ND	14	0.2	<0.1
3	NFB	NFB	15	0.2	0.1
4	0.4[c]	ND	16	0.3	0.3
5	0.6[c]	ND	18	0.2	<0.1
6	0.1[c]	NFB	22	<0.1	<0.1
7	0.1	NFB	35	<0.1	0.1
8	0.1[c]	NFB	39	<0.1	0.1
9	0.3	<0.1	42	0.1	0.2
10	13[+]	0.4[+]	46	0.3	0.2
11	0.4	0.1			

[a] GAC = WVW 14x40
Bed depth = 76 cm (30 inches) GAC
Loading rate = 6.1 m/hr (2.6 gpm/ft^2)
EBCT = 7.2 minutes
[b] GC/Hall detector, approximate lower detection level = 0.1 ug/L
[c] Co-elution with 1,1,1-trichloroethane
ND = not detected
NFB = not found after blank correction
+ = GC/MS confirmed as carbon tetrachloride

1.0 ug/L and the compound was not detected in the effluent. During the 10th week, the influent concentration was 0.8 ug/L (GC/MS confirmed) and the effluent concentration was 0.4 ug/L (GC/MS confirmed). During the 35th week, the influent concentration was 0.5 ug/L and the compound was not detected in the effluent. The precision of field data for chlorobenzene (Appendix C, Table C-7) indicates these influent and effluent concentrations are different.

1,4-Dichlorobenzene--1,4-dichlorobenzene was found with some frequency in the GAC influent. Evaluation of adsorption of this and other base-neutral extractable compounds was complicated by the losses during extraction (Section 5, page 30). 1,4-dichlorobenzene adsorption data not corrected for extraction losses are presented in Table 19. Concentrations in the waters sampled are, therefore, somewhat higher than those presented. Further, precision of field data for the compound indicates that the variability for the data presented in Table 19 may be ± 70% (Appendix E, Table E-1); therefore, influent and effluent concentrations of 1,4-dichlorobenzene cannot be differentiated. These data do not imply exhaustion. They indicate, however, the GC/MS confirmed presence of 1,4-dichlorobenzene in the GAC effluent, at concentrations that cannot be differentiated from those influent, as early as the 5th week of operation.

Unidentified Base-Neutral Extractable Halocarbons--Adsorption data for an unknown base-neutral extractable halocarbon are presented in Table 20. When using the procedure described in Appendix D, the compound has the same elution time as aldrin; however, the compound is not believed to be aldrin because repeated GC/MS confirmation attempts for aldrin proved negative. Further, the

TABLE 19. REMOVAL OF 1,4-DICHLOROBENZENE BY VIRGIN GRANULAR ACTIVATED CARBON[a]
HUNTINGTON WATER CORPORATION, JULY 1977-MARCH 1978

Week of Operation	Concentration,[b,c] ug/L Influent	Concentration,[b,c] ug/L Effluent	Week of Operation	Concentration,[b,c] ug/L Influent	Concentration,[b,c] ug/L Effluent
1	ND	ND	11	<0.1	<0.1
2	ND	ND	12	0.6	ND
3	ND	ND	13	<0.1	ND
5	0.8	1.0$^+$	14	0.4	0.1
6	1.0	0.7	22	1.4$^+$	ND
7	0.1	ND	31	<0.1	ND
8	0.2	0.7	35	0.2	ND
10	1.2$^+$	0.5$^+$			

[a] GAC = WVW 14x40
Bed depth = 76 cm (30 inches) GAC
Loading rate = 6.1 m/hr (2.6 gpm/ft^2)
EBCT = 7.2 minutes
[b] Base-neutral extraction, GC/Hall detector, approximate lower detection level = 0.1 ug/L
[c] NOT CORRECTED FOR EXTRACTION LOSSES.
ND = not detected
+ = GC/MS confirmed as 1,4-dichlorobenzene

compound could not be GC/MS identified (Section 7, page 163). The extraction recovery of the compound is not known because its identity is not known. The precision of the data presented in Table 20 may be ± 20% above 0.1 ug/L (Appendix E, Table E-13). These data do indicate adsorption during the first two months of operation (breakthrough was not observed until week 10) and suggest adsorption beyond that time.

TABLE 20. REMOVAL OF AN UNIDENTIFIED BASE-NEUTRAL EXTRACTABLE HALOCARBON[a] BY VIRGIN GRANULAR ACTIVATED CARBON[b], HUNTINGTON WATER CORPORATION
JULY 1977-MARCH 1978

Week of Operation	Concentration,[c] ug/L Influent	Concentration,[c] ug/L Effluent	Week of Operation	Concentration,[c] ug/L Influent	Concentration,[c] ug/L Effluent
1	0.4	ND	11	0.1	0.1
2	0.2	ND	12	3.5$^-$	<0.1
3	0.2	ND	13	0.7	0.1
5	ND	ND	14	0.2	0.3
6	0.1	ND	15	0.2	<0.1
7	0.2$^-$	ND	22	ND	ND
8	<0.1	ND	31	ND	ND
9	0.2	ND	35	ND	ND
10	0.4	ND			

[a] Using procedure described in Appendix D, compound has same elution time as aldrin.
[b] GAC = WVW 14x40
Bed depth = 76 cm (30 inches) GAC
Loading rate = 6.1 m/hr (2.6 gpm/ft^2)
EBCT = 7.2 minutes
[c] NOT CORRECTED FOR EXTRACTION LOSSES.

ND = not detected
$^-$ = Found not to be aldrin by GC/MS

At Huntington and at other utilities, base-neutral extractable halocarbons were occasionally detected in finished waters but were rarely found in raw waters. As discussed in Section 7, these may be products of chlorination or may be contaminants in the chlorine supply. At Huntington, one such halocarbon was not detected in raw water but was detected 12 of 19 times in finished water. Another such halocarbon was not detected in raw water but was detected 8 of 19 times in finished waters. When detected, concentrations in GAC influent waters were lower than concentrations in finished waters (Table 21). Although the influent concentrations were low and detection was infrequent, the data suggest that the halocarbons were adsorbed.

TABLE 21. REMOVAL OF UNIDENTIFIED BASE-NEUTRAL EXTRACTABLE HALOCARBONS BY VIRGIN GRANULAR ACTIVATED CARBON,[a] HUNTINGTON WATER CORPORATION JULY 1977-MARCH 1978

Week of Operation	Concentration,[b] ug/L			
	Halocarbon[c,d]		Halocarbon[d,e]	
	Influent	Effluent	Influent	Effluent
1	<0.1	ND	0.4	ND
2	<0.1	ND	ND	ND
3	<0.1	ND	ND	ND
4	<0.1	ND	<0.1	ND
5	ND	ND	ND	ND
6	ND	ND	<0.1	ND
7	0.2	ND	0.5	ND
8	ND	ND	ND	ND
9	0.1	ND	0.6	ND
10	ND	ND	ND	ND
11	<0.1	ND	<0.1	ND
12	<0.1	ND	ND	ND
13	ND	ND	ND	ND
14	<0.1	ND	ND	ND
15	ND	ND	ND	ND
18	--	ND	--	ND
20	--	ND	--	ND
22	<0.1	ND	ND	ND
26	--	<0.1	--	ND
31	ND	ND	ND	ND
35	ND	ND	<0.1	ND

[a] GAC = WVW 14x40
Bed depth = 76 cm (30 inches) GAC
Loading rate = 6.1 m/hr (2.6 gpm/ft^2)
EBCT = 7.2 minutes

[b] NOT CORRECTED FOR EXTRACTION LOSSES

[c] Using procedure described in Appendix D, compound has retention time of approximately 0.75 relative to hexachlorobenzene.

[d] Quantification based on hexachlorobenzene.

[e] Using procedure described in Appendix D, compound has retention time of approximately 0.77 relative to hexachlorobenzene.

ND = not detected

Carbon Tetrachloride Desorption from Older GAC--

When effluents from the older GAC filter/adsorbers were sampled, concentrations of carbon tetrachloride were found to be higher than influent concentrations. These data are presented in Table 22. These GAC beds were in place in February 1977 when a large carbon tetrachloride spill (raw water concentrations in excess of 100 ug/L) moved through the Huntington plant. These data indicate desorption of carbon tetrachloride that had been earlier adsorbed by the GAC. USEPA reported desorption of carbon tetrachloride from GAC for a period of nine months following extremely high influent carbon tetrachloride loading.[18]

TABLE 22. REMOVAL OF CARBON TETRACHLORIDE BY OLDER GRANULAR ACTIVATED CARBON,[a] HUNTINGTON WATER CORPORATION

GAC placed October 1976			GAC placed April 1975		
Week of Operation	Concentration,[b] ug/L Influent	Concentration,[b] ug/L Effluent	Week of Operation	Concentration,[b] ug/L Influent	Concentration,[b] ug/L Effluent
9	ND	2.2[c]	27	ND	1.5[c]
9½	ND	2.3[c]	27½	ND	0.7[c],+
11	0.5	1.0	28	0.1	0.6
13	0.2	0.4	29	0.2	0.7
14	0.1	0.3	31	0.2	0.3
			32	0.1	0.2

[a]GAC = WVW 14x40
Bed depth = 76 cm (30 inches) GAC
Loading rate = approximately 6.1 m/hr (2.6 gpm/ft^2)
EBCT = approximately 7.2 minutes
[b]GC/Hall detector, approximate lower detection level = 0.1 ug/L
[c]Co-elution with 1,1,1-trichloroethane
+ = GC/MS confirmed as carbon tetrachloride
ND = not detected

Bacteriological Evaluation--

Microbiological characteristics of the Ohio River raw water and the GAC influent and effluent waters are presented in Table 15. These data indicate that during the 31-week study, the mean density of total coliforms in the Ohio River raw water was 3,400/100 mL. After the processes of chlorination, coagulation and settling, the density of total coliforms in the GAC influent water was always <1/100 mL. Coliform densities were apparent in the GAC effluent and seem to be related to source water temperatures. During weeks three through nine, when the raw water temperatures were 26-28°C (79-82°F), the total coliform densities in the GAC effluent ranged from <1 to 8/100 mL. During the remainder of the study period, the water temperatures declined from 27°C to 2°C (80°F to 35°F) and the GAC effluent coliform densities were always <1/100 mL with the exception of a density of 1/100 mL during week 12.

A similar occurrence was observed in the general bacterial population data. During the first ten weeks of the study, the data indicate that GAC effluent standard plate count bacterial densities occasionally exceeded influent densities. After ten weeks, GAC effluent bacterial densities were consistently lower than influent densities.

The higher densities of coliforms and of the general bacterial population in the effluent water during the first ten weeks do not seem to correlate with either raw water turbidity or raw water total coliform densities during that time. These parameters had lower values during weeks one through ten than the 31-week mean value. The raw water temperatures during the first ten weeks were in a range that may have favored regrowth of bacteria on the carbon bed. Other growth conditions may have been favorable on the GAC with the reduction of free chlorine on the carbon, the provision of a large surface area and the possible accumulation of nutrients.

Finished water quality was adequately maintained during the study at a total coliform density of <1/100 mL and a standard plate count density of <500/mL with the application of chlorine following GAC adsorption/filtration.

Findings--

1. Trihalomethane formation occurred during treatment after chlorine application and generally varied with water temperature.

2. During summer months, virgin WVW 14x40 GAC receiving chlorinated, settled water and operating in the filtration/adsorption mode in a bed designed for sand filtration was exhausted for the removal of:

   a. chloroform at seven to eight weeks of operation.

   b. bromodichloromethane at eleven to 14 weeks of operation.

   c. dibromochloromethane at eleven to 14 weeks of operation.

   d. instantaneous TTHM at seven to eight weeks of operation.

   e. THMFP at seven to ten weeks of operation.

3. WVW 14x40 GAC receiving chlorinated and settled water in the filtration/adsorption mode in a bed designed for sand filtration was not exhausted for the removal of bromoform for periods of from one to two years.

4. WVW 14x40 GAC operated in the filtration/adsorption mode in beds designed for sand filtration:

   a. was an effective barrier for high influent concentrations (13 ug/L) of carbon tetrachloride.

   b. did not reach breakthrough for carbon tetrachloride for nine weeks.

   c. was passing carbon tetrachloride at concentrations (0.1-0.3 ug/L) that could not be differentiated from influent concentrations after four months of operation.

   d. was passing 1,4-dichlorobenzene at concentrations that could not be differentiated from influent concentrations after five weeks of operation.

5. One and two-and-one-half year old WVW 14x40 GACs receiving chlorinated and settled water in the filtration/adsorption mode in a bed designed for

sand filtration were exhausted for the removal of chloroform, bromodichloromethane, dibromochloromethane, instantaneous TTHM and THMFP.

6. One and two-and-one-half year old WVW 14x40 GACs operated in the filtration/adsorption mode in beds designed for sand filtration desorbed carbon tetrachloride.

7. With temperatures in excess of 10°C, total coliform densities and standard plate count densities in GAC effluent waters occasionally exceeded densities in GAC influent waters.

8. The bacterial quality of the finished water was satisfactory with clear well chlorination.

Beaver Falls Authority

Background--

Three virgin GAC beds were evaluated for adsorption of influent instantaneous trihalomethanes and influent unreacted precursor (THMFP). The utility had conducted pilot column studies with several GACs for taste and odor control but not to determine optimum selection of GAC or bed depth for organics control.

The GACs replaced sand. One bed was filled with 61 cm (24 inches) of Calgon's Filtrasorb 400 on top of 30 cm (12 inches) of sand and gravel, backwashed several times to remove fine particulates, and held static under finished water for six days. A second bed was filled with 61 cm of Calgon's Filtrasorb C on top of 30 cm of sand and gravel, backwashed several times, and then held static under finished water for one day. Filtrasorb C was a Calgon research product designed for adsorption of trihalomethanes. A third bed was filled with 61 cm of ICI's Hydrodarco 8x16 on top of 30 cm of sand and backwashed several times. All three beds were placed in service simultaneously.

The same chlorinated, coagulated and settled water was applied to the three GAC filter/adsorbers. The filters were geometrically identical except that the Calgon filters had tile bottoms while the ICI filter had a porous plate bottom. Although the beds were chosen so that their hydraulic operation would be identical, the hydraulic data collected during the study indicated that the bed containing Filtrasorb C had passed approximately 10 percent more volume than did the other beds. These data are presented in Table 23. The ICI carbon required less frequent backwashing than did the Calgon carbons. The ICI carbon was backwashed one to two times weekly throughout the study. The Calgon carbons were backwashed two to five times weekly during the first 21 weeks and one to three times weekly thereafter.

Treatment is illustrated in Figure 33. Water quality data for the utility are presented in Tables 24 and 25. The virgin GAC beds represented only 30% of the plant capacity.

A problem at the contract laboratory resulted in a significant loss of samples collected during the first several weeks of the study. Thus, THM data

TABLE 23. HYDRAULIC DATA (MEAN VALUES), BEAVER FALLS AUTHORITY

Parameter	GAC Filtrasorb 400	 Filtrasorb C	 Hydrodarco 8x16
Loading rate, m/hr	3.1	3.5	3.1
(gpm/ft^2)	(1.3)	(1.5)	(1.3)
Empty bed contact time, minutes	11.3	10.1	11.4
GAC depth, cm	61	61	61
(inches)	(24)	(24)	(24)
sand and gravel depth, cm	30	30	30
(inches)	(12)	(12)	(12)

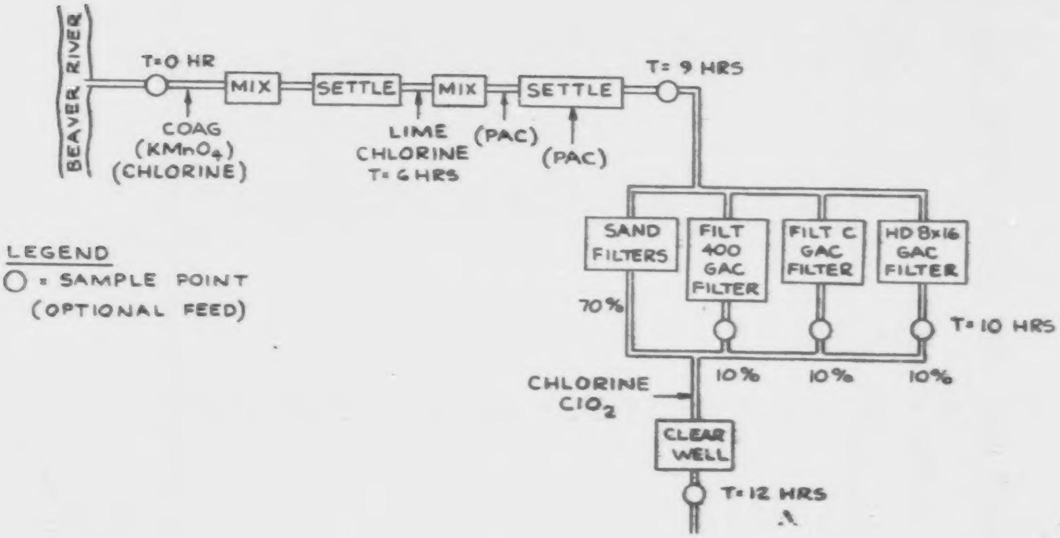


Figure 33. Water treatment scheme, Beaver Falls Authority, Eastvale Plant, 17,000 cu m/day (4.5 MGD).

TABLE 24. WATER QUALITY DATA (MEAN VALUES) BEAVER FALLS AUTHORITY SEPTEMBER 1977-APRIL 1978

Week of Operation	Raw Mean pH = 7.2			GAC Influent (Settled) Mean pH = 7.4				
				Chlorine[a]				
	Temp, °C	Turbidity[b]	TC[c] x 10^3	Free	Total	Turbidity[b]	TC[c]	SPC[d]
1	21	44	98	2.0	--	5.6	<1	--
2	21	28	71	1.7	1.7	4.8	<1	--
3	15	22	140	1.3	1.4	2.3	<1	--
4	11	9.5	150	1.1	1.3	2.9	<1	100
5	16	7.5	39	1.2	1.4	2.5	<1	800
6	16	9	190	1.4	1.6	3.3	<1	350
7	16	10	80	1.1	1.2	3.6	<1	10
8	10	9	98	1.0	1.0	3.2	<1	42
9	10	16	220	1.3	1.6	4.6	2	110
10	8	10	120	1.0	1.3	4.5	<1	33
11	6	14	120	1.4	1.6	3.7	<1	95
12	3	10	69	1.0	1.1	5.9	1	360
13	4	22	89	1.2	1.7	4.6	<1	660
14	2	10	75	1.3	1.5	6.6	1	200
15	1	10	65	1.0	1.2	4.8	<1	120
17	1	12	48	1.4	1.7	5.9	<1	150
18	1	8	27	1.0	1.1	5.5	<1	33
21	1	14	6	0.4	1.6	6.4	<1	30
23	4	10	23	0.3	1.6	5.8	<1	24
25	4	150	84	TR	1.4	6.6	<1	38
27	7	12	13	--	1.4	6.3	<1	58
29	10	8	24	0.2	1.1	1.7	<1	33
32	11	6	8.4	0.2	1.6	1.9	<1	17

[a] Chlorine, mg/L

[b] Turbidity, NTU

[c] Total coliform/100 mL

[d] Standard plate count/mL

TR = trace

TABLE 25. WATER QUALITY DATA (MEAN VALUES) BEAVER FALLS AUTHORITY SEPTEMBER 1977-APRIL 1978

		GAC Effluent														
		Filtrasorb 400 Mean pH = 7.3					Filtrasorb C Mean pH = 7.3					HD 8x16 Mean pH = 7.3				
		Chlorine[a]					Chlorine[a]					Chlorine[a]				
Week of Operation	Raw Water Temp, °C	Free	Total	Turb[b]	TC[c]	SPC[d]	Free	Total	Turb[b]	TC[c]	SPC[d]	Free	Total	Turb[b]	TC[c]	SPC[d]
1	21	ND	ND	0.4	64	--	ND	ND	0.5	85	--	ND	ND	0.6	46	--
2	21	ND	ND	0.4	75	--	ND	ND	0.3	95	--	ND	ND	0.4	25	--
3	15	ND	ND	0.3	98	1,000	ND	ND	0.4	130	740	ND	ND	0.3	33	1,700
4	11	ND	ND	0.3	45	1,400	ND	ND	0.3	50	60,000	ND	ND	0.3	23	1,100
5	16	ND	ND	0.4	34	25,000	ND	ND	0.4	28	42,000	ND	ND	0.3	12	3,800
6	16	TR	<0.1	0.6	42	2,000	TR	<0.1	0.5	12	40,000	<0.1	0.2	0.6	13	3,000
7	16	TR	<0.1	0.3	28	20,000	TR	<0.1	0.4	12	52,000	TR	<0.1	0.3	2	45,000
8	10	TR	<0.1	0.4	22	29,000	TR	<0.1	0.4	21	32,000	TR	<0.1	0.4	8	92,000
9	10	TR	TR	0.5	13	6,500	TR	<0.1	0.6	7	6,500	TR	<0.1	0.4	2	21,000
10	8	TR	<0.1	0.3	12	1,600	TR	<0.1	0.4	18	1,800	TR	<0.1	0.3	5	1,800
11	6	TR	<0.1	0.6	2	960	TR	<0.1	0.5	1	820	TR	<0.1	0.5	1	900
12	3	TR	<0.1	0.6	1	270	TR	<0.1	0.6	2	380	TR	<0.1	0.7	<1	320
13	4	TR	<0.1	0.4	<1	480	TR	<0.1	0.4	<1	540	TR	<0.1	0.4	<1	380
14	2	TR	TR	0.1	1	440	TR	<0.1	0.3	<1	110	TR	<0.1	0.1	<1	200
15	1	TR	<0.1	0.4	<1	44	TR	<0.1	0.3	<1	50	TR	<0.1	0.4	<1	74
17	1	TR	<0.1	0.4	<1	50	TR	<0.1	0.5	<1	16	TR	0.1	0.5	<1	26
18	1	TR	<0.1	0.5	<1	21	TR	<0.1	0.5	<1	20	TR	<0.1	0.6	<1	9
21	1	TR	0.3	0.6	<1	30	TR	0.4	0.6	<1	23	<0.1	0.4	0.7	<1	47
23	4	TR	0.4	0.6	<1	13	TR	0.2	0.5	<1	10	TR	0.4	0.4	<1	15
25	4	TR	0.2	0.6	<1	21	TR	0.2	0.6	<1	35	TR	0.2	0.6	<1	24
27	7	--	0.1	0.3	<1	41	--	0.1	0.3	<1	27	--	0.2	0.4	<1	10
29	10	--	0.1	0.3	<1	31	--	0.1	0.3	<1	28	--	0.1	0.3	<1	17
32	11	--	0.3	0.3	<1	69	--	0.2	0.3	<1	82	--	0.3	0.3	<1	19

[a] Chlorine, mg/L
[b] Turbidity, NTU
[c] Total coliform/100 mL
[d] Standard plate count/mL

TR = trace
ND = not detected

presented for the Beaver Falls study represent approximately 60% of the samples collected during the first six weeks the virgin beds were in operation. Further, no GAC influent data representing the first four weeks of operation are presented because of a sampling problem.

Trihalomethane Adsorption by Filtrasorb 400--

Figure 34 is a plot of the removal of instantaneous TTHM by Filtrasorb 400 during the first 32 weeks of operation of the virgin bed. The data indicate that the GAC was exhausted for the removal of instantaneous TTHM at nine to ten weeks of operation.

The GAC was exhausted for the removal of THMFP at approximately eleven weeks of operation as illustrated in Figure 34. The expected variability of an instantaneous TTHM concentration may be within ± 20%; the expected variability of a terminal TTHM concentration may be within ± 16% (Appendix C, Figure C-11 and C-12). Therefore, the expected variability of the THMFP concentration may be greater than ± 20%. Beyond the eleventh week of operation, influent and effluent THMFP concentrations were within ± 20% of one another and thus could not be differentiated.

The adsorption of individual instantaneous THMs is plotted in Figure 35. These data indicate that the GAC was exhausted for the removal of chloroform at nine to ten weeks of operation. In the same manner, Figure 35 indicates that the GAC was exhausted for the removal of bromodichloromethane at eight to ten weeks of operation, and exhausted for the removal of dibromochloromethane at ten to 14 weeks of operation.

Trihalomethane Adsorption by Hydrodarco 8x16--

Figure 36 indicates that HD 8x16 was exhausted for the removal of TTHM at eight to ten weeks of operation and exhausted for the removal of THMFP at approximately eleven weeks of operation. Figure 37 indicates that the GAC was exhausted for the removal of chloroform, bromodichloromethane and dibromochloromethane at eight to ten weeks of operation.

Trihalomethane Adsorption by Filtrasorb C--

Data presented in Figures 38 and 39 indicate that Filtrasorb C was in operation several weeks longer than were the other GACs before reaching exhaustion for the removal of instantaneous trihalomethanes. As illustrated by Figure 38, Filtrasorb C was exhausted for the removal of instantaneous TTHM at 12 to 15 weeks of operation. Although exhaustion was not apparent until the 15th week of operation, influent and effluent concentrations were within 20% of one another beyond the 12th week of operation and could not be differentiated. (Other GACs were exhausted for TTHM removal at seven to eight weeks of operation.) Figure 39 indicates that the Filtrasorb C was exhausted for the removal of chloroform and bromodichloromethane at 12 to 15 weeks and dibromochloromethane at 14 to 15 weeks. As shown in Figure 38, the GAC was exhausted for the removal of THMFP at approximately 12 weeks of operation.

Bromoform and Dichloroiodomethane--

The adsorptive capacity of the three GACs for bromoform and dichloroiodomethane could not be evaluated because influent and effluent concentrations, when found, were typically at or below 0.1 ug/L where precision of field data

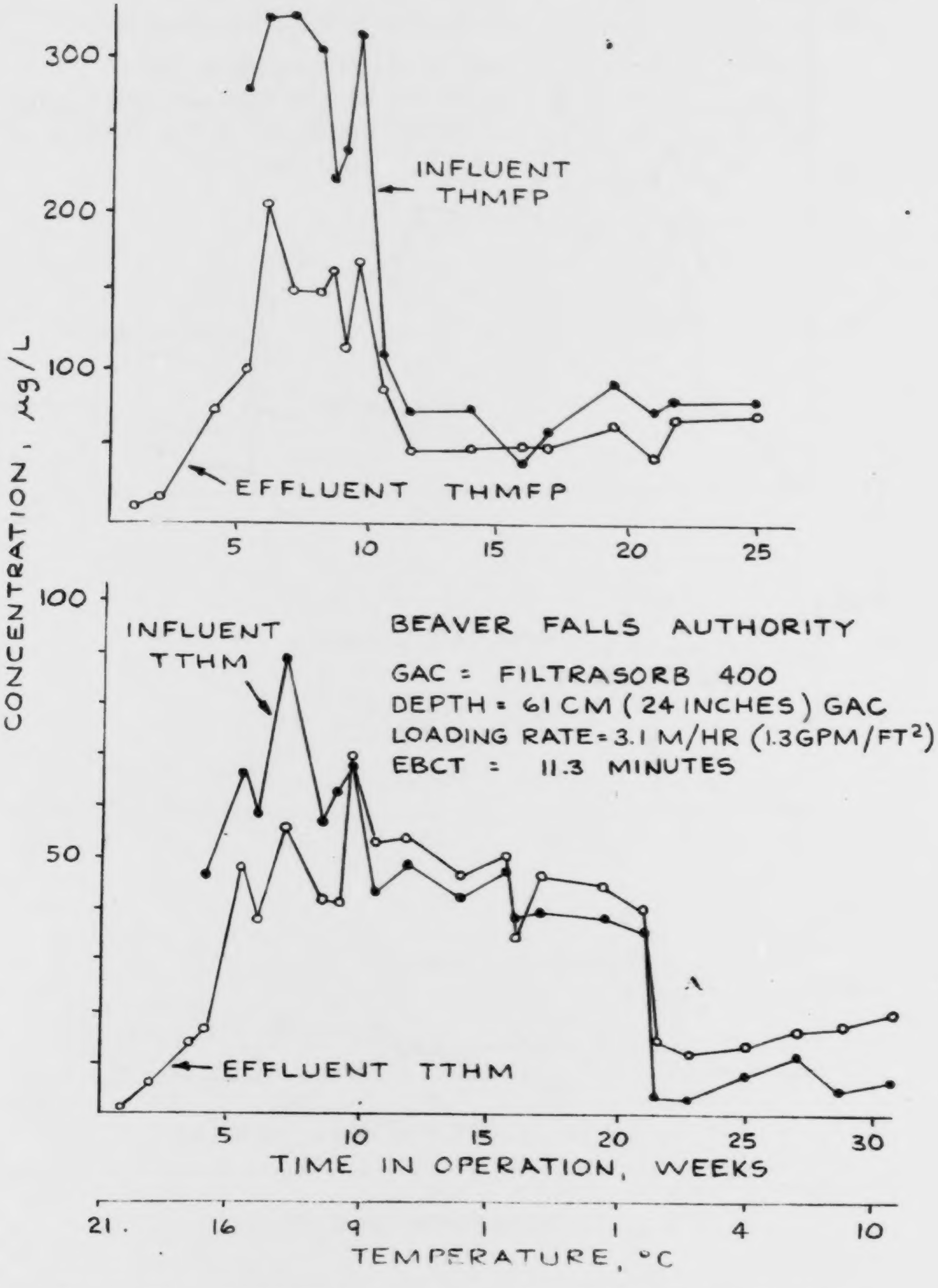


Figure 34. Trihalomethane removal by granular activated carbon.

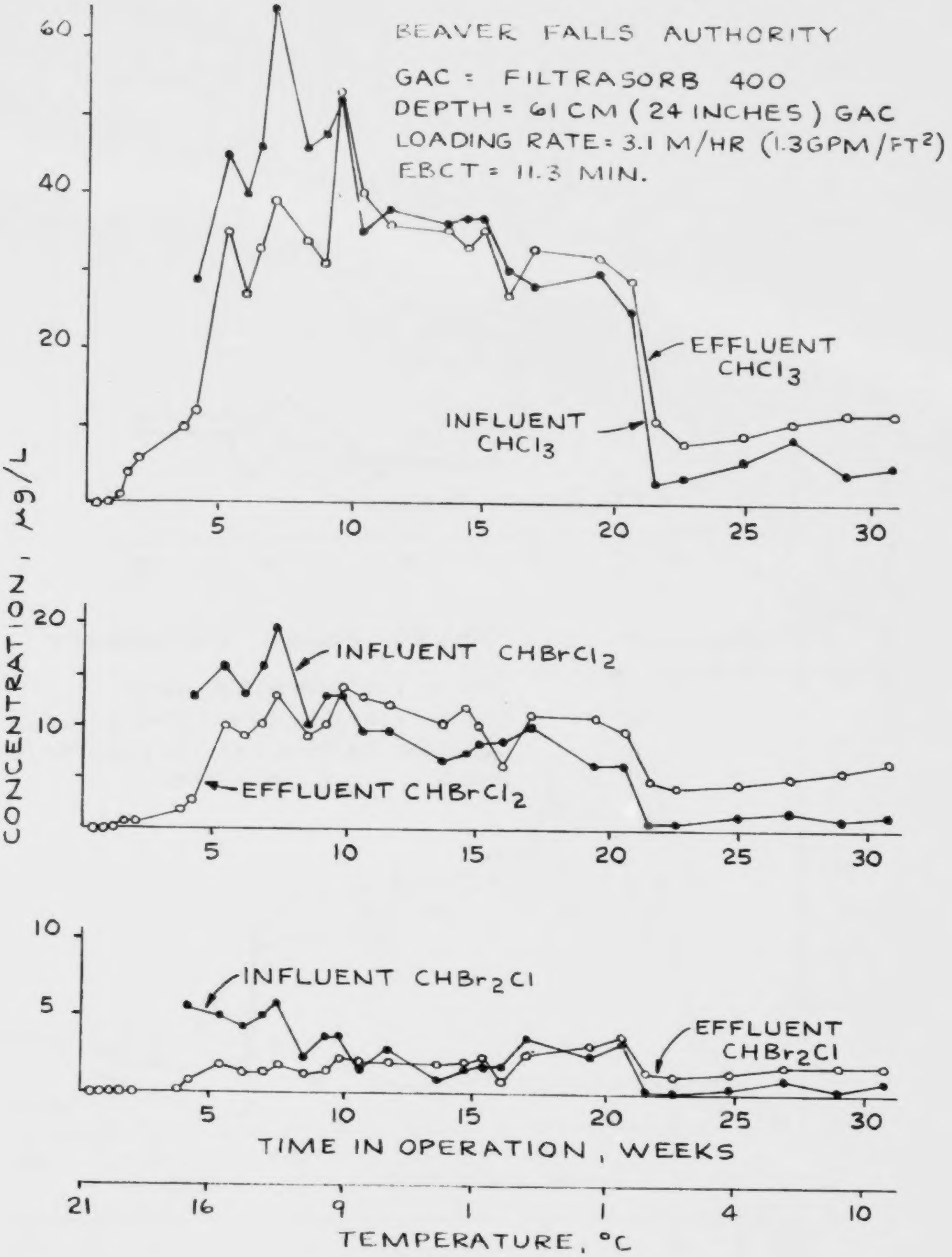


Figure 35. Trihalomethane removal by granular activated carbon.

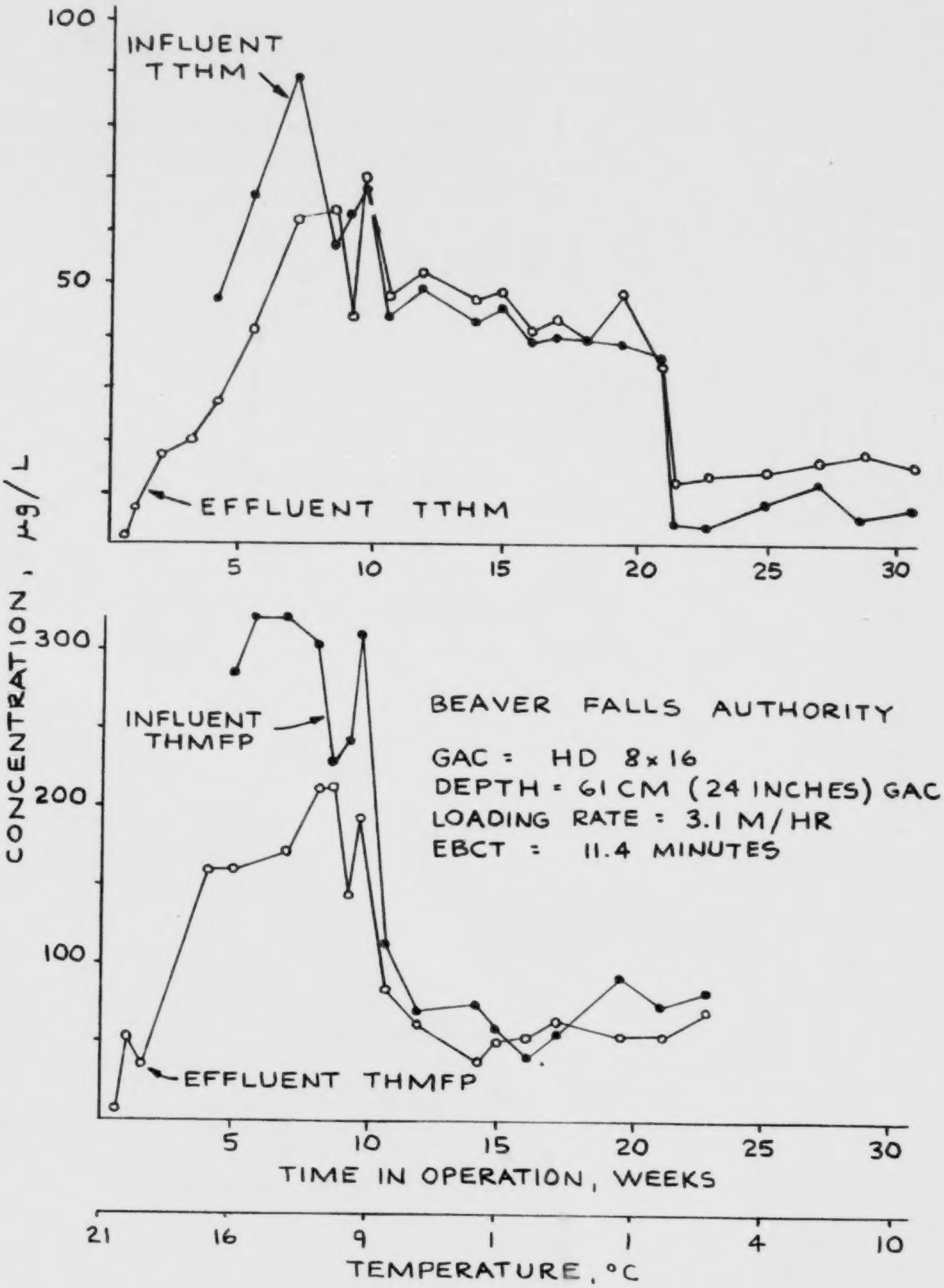


Figure 36. Trihalomethane removal by granular activated carbon.

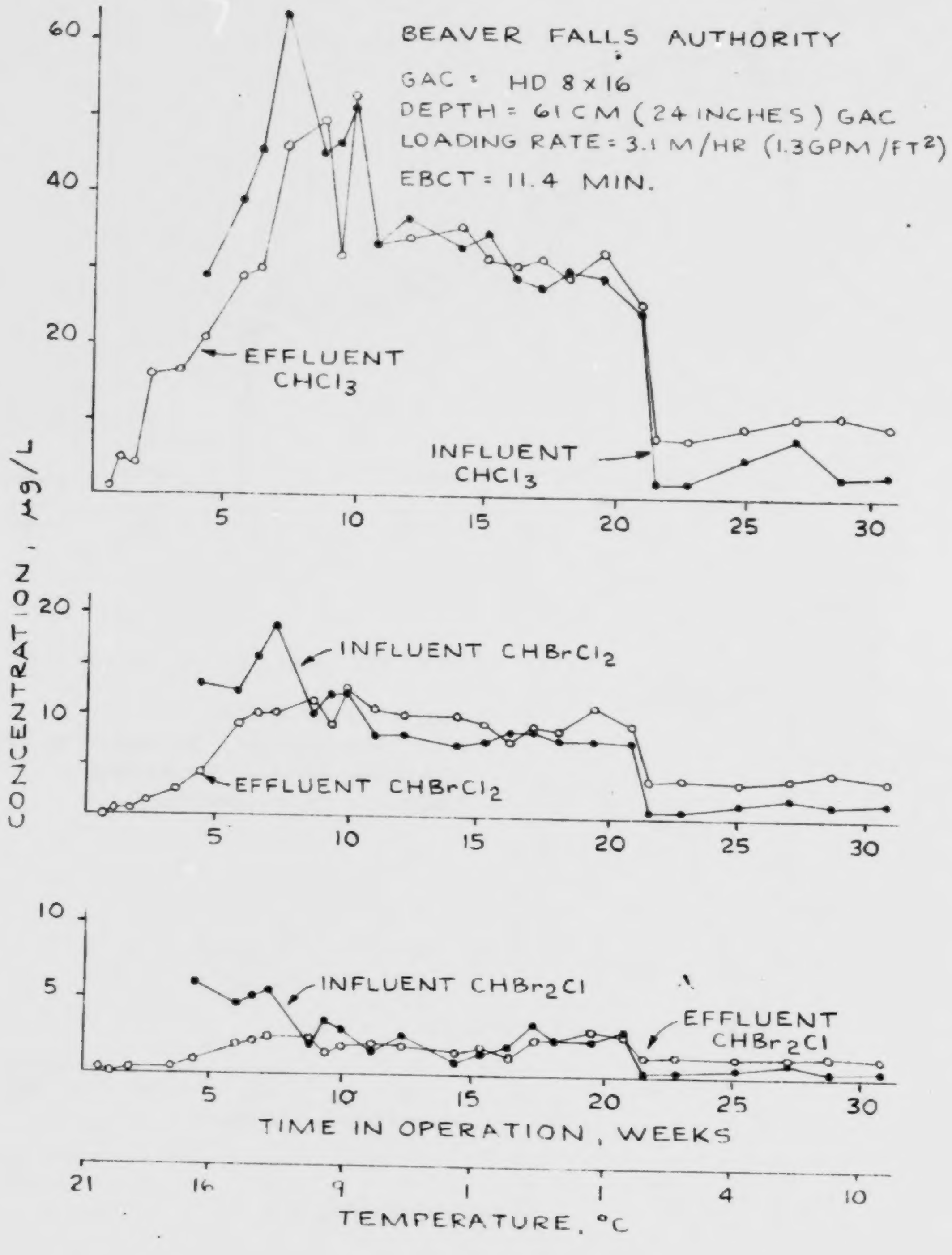


Figure 37. Trihalomethane removal by granular activated carbon.

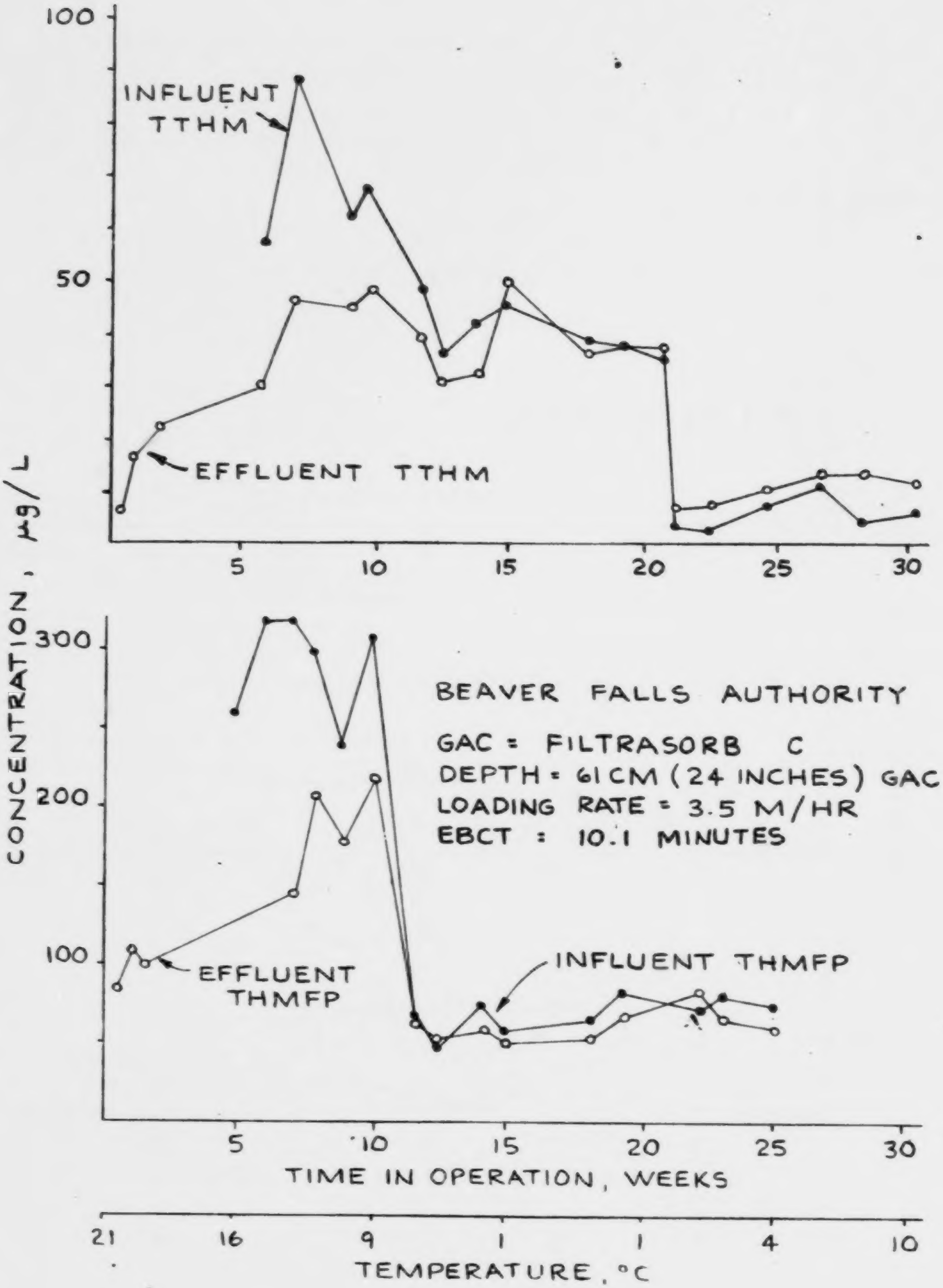


Figure 38. Trihalomethane removal by granular activated carbon.

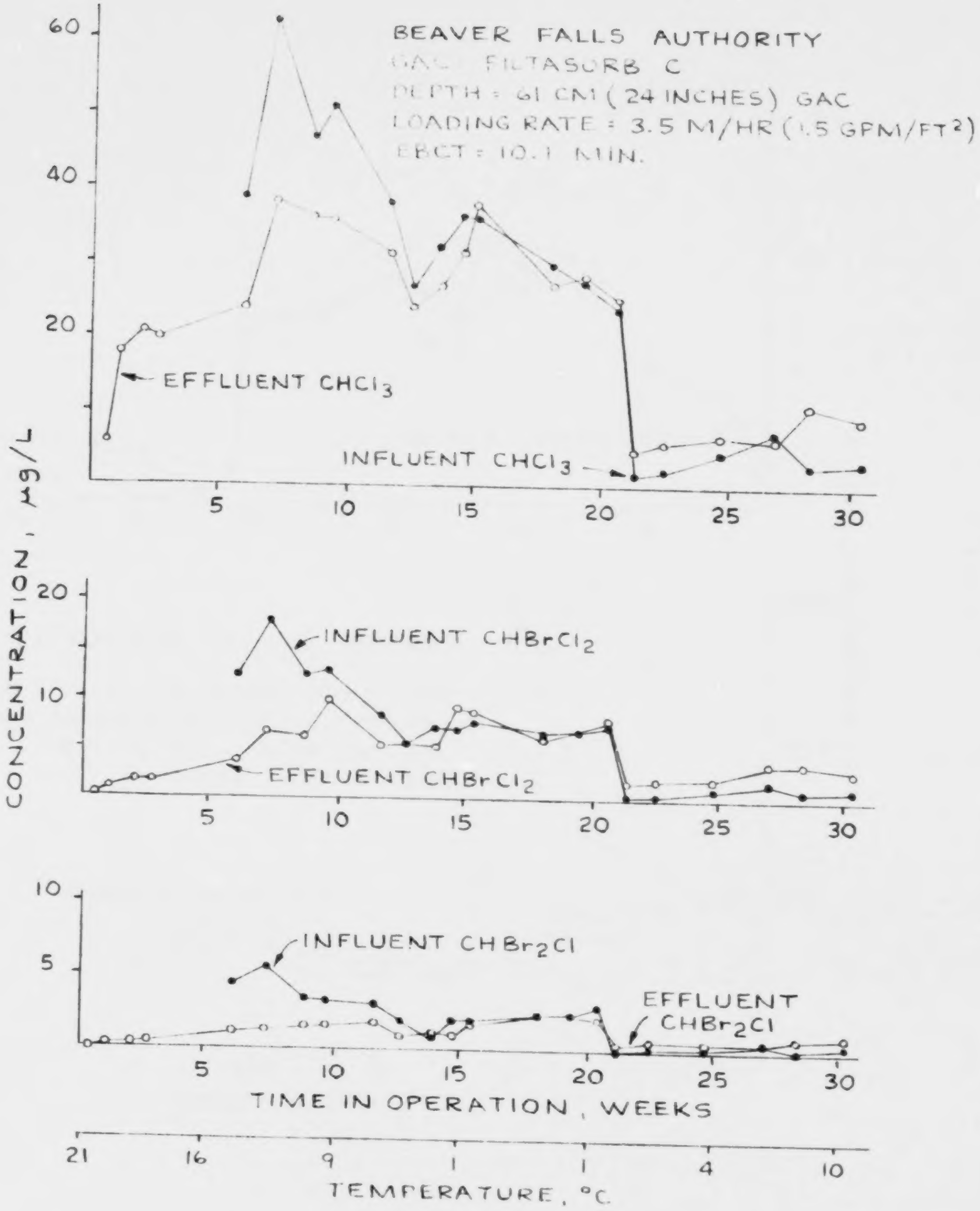


Figure 39. Trihalomethane removal by granular activated carbon.

(Appendix C, Figure C-9 and Table C-6) indicates that they could not be differentiated.

Desorption of Trihalomethanes--

Near the 21st week of the study, high chlorine demand caused the utility to stop the practice of breakpoint chlorination. Figures 34 through 39 indicate that influent concentrations of individual THMs and of TTHM decreased sharply with little or no free chlorine present. These data indicate that effluent concentrations were significantly higher than influent concentrations, i.e., expected variability of ± 19% to ± 26% (Appendix C, Figures C-1, 2, 4, 6 and 11) would not explain the difference, beyond the 21st week of operation. It is likely that the three GACs were desorbing THMs beyond the 21st week of operation.

Adsorption of Priority Pollutants and Other Compounds--

Compounds other than trihalomethanes were searched for in GAC influent and effluent waters to determine their presence or absence and, if present, their adsorption by virgin GAC. Purgeable halocarbons and base-neutral extractable halocarbons were detected infrequently. When detected, their concentrations were low and in ranges where precision of the field data indicates that influent and effluent concentrations could not be differentiated, i.e., the compounds were typically detected at or below 0.2 ug/L. Until more sensitive analytical procedures are employed, the adsorptive capacity of GAC for these compounds at low concentrations cannot be evaluated; however, some data at low concentration proved informative.

Carbon Tetrachloride--Carbon tetrachloride was not detected in raw water, but was occasionally detected in treated waters. Its presence likely resulted from contamination of the chlorine supply. When detected, concentrations were typically below 0.2 ug/L where precision can be ± 100%. Carbon tetrachloride data for one sample day are presented in Table 26. These data indicate introduction of carbon tetrachloride during treatment and demonstrate the presence of the compound in the GAC effluent at concentrations that could not be differentiated from those in the GAC influent. Thus, the carbons were not acting as a barrier to routine influent loading after seven months of operation. This does not imply that exhaustion had occurred or that the carbons would not act as an effective barrier to a higher influent load.

TABLE 26. CARBON TETRACHLORIDE DATA
BEAVER FALLS AUTHORITY - APRIL 26, 1978

Water	Raw	GAC Influent	GAC Effluent[a]			Finished
			F400	FC	ICI	
Concentration,[b] ug/L	ND$^-$	0.3$^+$	<0.1	0.2$^+$	0.2	0.2

[a] GAC in operation for seven months. Hydraulic data in Table 23.
[b] GC/Hall detector, approximate lower detection level = 0.1 ug/L
ND = not detected
+ = GC/MS confirmed as carbon tetrachloride
- = Carbon tetrachloride not detected by GC/MS at 0.1 ug/L

1,4-Dichlorobenzene--1,4-dichlorobenzene was found occasionally in the GAC influent. Evaluation of adsorption of this and other base-neutral extractable compounds was complicated by the losses during extraction (Section

5, page 20). 1,4-dichlorobenzene adsorption data, not corrected for extraction losses, are presented in Table 27. Concentrations in the waters sampled are somewhat higher than those presented. Further, precision of field data for the compound indicates that the variability for the data presented in Table 27 can be ± 70% (Appendix E, Table E-1); therefore, influent and effluent concentrations of 1,4-dichlorobenzene cannot be differentiated. These data do not imply exhaustion but indicate the GC/MS confirmed presence of 1,4-dichlorobenzene in GAC effluents at concentrations that cannot be differentiated from those in the influent after three months of operation.

TABLE 27. REMOVAL OF 1,4-DICHLOROBENZENE BY VIRGIN GRANULAR ACTIVATED CARBONS BEAVER FALLS AUTHORITY, SEPTEMBER 1977-MARCH 1978

	Concentration,[a,b] ug/L			
		Effluent[c]		
Week of Operation	Influent	F400	FC	ICI
1	--	ND	<0.1	ND
2	--	ND	ND	--
3	--	<0.1	--	--
4	--	ND	ND	ND
5	ND	ND	--	ND
6	--	ND	0.1	ND
7	<0.1	--	ND	ND
9	--	<0.1	ND	--
10	ND	ND	ND	ND
11	0.3	ND	0.2^-	--
12	0.2	0.3	0.5^+	0.2
13	0.1^+	ND	ND^+	<0.1
15	ND	ND	ND	ND
18	<0.1	<0.1	<0.1	0.1^+
21	<0.1	<0.1	<0.1	0.1^+
23	<0.1	<0.1	ND	<0.1
27	--	--	<0.1	ND

[a] Base-neutral extraction, GC/Hall detector, approximate lower detection level = 0.1 ug/L

[b] NOT CORRECTED FOR EXTRACTION LOSSES

[c] Hydraulic data in Table 23.

ND = not detected

+ = GC/MS confirmed as 1,4-dichlorobenzene

- = 1,4-dichlorobenzene not detected by GC/MS at approximately 0.15 ug/L

Unidentified Base-Neutral Extractable Halocarbons--At Beaver Falls, base-neutral extractable halocarbons were occasionally detected in finished waters but rarely found in raw waters. They are believed to be products of chlorination or contaminants in the chlorine supply (Section 7). At Beaver Falls, one such halocarbon was not detected in raw water but was detected 13 of 20 times in finished water. Another such halocarbon was detected two of 18 times in raw water but was detected 12 of 18 times in finished waters. When detected, concentrations in GAC influent waters were lower than concentrations in finished waters. Adsorption data for these halocarbons are presented in Tables 28 and 29. Data presented in Table 28 suggest that the halocarbon was present in GAC effluents at concentrations that cannot be differentiated from those influent after three months of operation. Data presented in Table 29 suggest that Filtrasorb 400 better adsorbed the halocarbon in the first four months of operation than did the other GACs. However, after four months of operation, the halocarbon was present in GAC effluents at concentrations that could not be differentiated from GAC influent concentrations.

TABLE 28. REMOVAL OF UNIDENTIFIED BASE-NEUTRAL EXTRACTABLE HALOCARBON[a] BY VIRGIN GRANULAR ACTIVATED CARBON BEAVER FALLS AUTHORITY, SEPTEMBER 1977-MARCH 1979

Week of Operation	Concentration,[a,b] ug/L			
		Effluent[c]		
	Influent	F400	FC	ICI
1	--	ND	ND	ND
2	--	ND	ND	--
3	--	ND	--	--
4	--	ND	ND	ND
5	0.6	ND	--	<0.1
6	--	ND	0.6	0.2
7	<0.1	--	<0.1	<0.1
9	--	ND	0.1	--
10	0.2	0.1	0.1	0.2
11	0.3^-	0.2	0.8^-	--
12	1.2	0.9	1.7^-	1.0
13	0.4	0.3	0.4^-	0.2
15	NQ	0.4	NQ	NQ
18	0.1	NQ	0.2	0.3^-
21	0.1	0.2	ND	0.1
23	ND	ND	ND	ND
27	--	--	ND	ND

[a] Using procedure described in Appendix D, compound has elution time of 2-chloronaphthalene. Quantification based on 2-chloronaphthalene.

[b] NOT CORRECTED FOR EXTRACTION LOSSES

ND = not detected

NQ = Present but not quantified

- = Found not to be 2-chloronaphthalene by GC/MS

Bacteriological Evaluation--

The microbiological characteristics of the raw water and the GAC influent water during the 32-week study are presented in Table 24 and the data for the GAC effluent waters are presented in Table 25. The Beaver River raw water was characterized during weeks one through 32 by a mean total coliform density of 91,000 organisms/100 mL.

A comparison of the total coliform bacterial data in Tables 24 and 25 indicates that the densities in the GAC effluent were in excess of influent densities during weeks one through 12. The GAC influent coliform densities were <1/100 mL during the entire study with three exceptions of ≤2/100 mL. During the first twelve weeks, mean coliform densities in the three GAC effluent waters were: 45/100 mL from Filtrasorb 400; 42/100 mL from Filtrasorb C;

TABLE 29. REMOVAL OF UNIDENTIFIED BASE-NEUTRAL EXTRACTABLE HALOCARBON[a] BY VIRGIN GRANULAR ACTIVATED CARBON BEAVER FALLS AUTHORITY, SEPTEMBER 1977-MARCH 1978

Week of Operation	Concentration,[a],[b] ug/L			
		Effluent[c]		
	Influent	F400	FC	ICI
1	--	ND	ND	ND
2	--	ND	ND	--
3	--	ND	--	--
4	--	ND	ND	ND
5	<0.1	ND	--	ND
6	--	ND	<0.1	<0.1
7	0.1	--	<0.1	ND
9	--	ND	<0.1	--
10	<0.1	ND	<0.1	<0.1
11	<0.1	ND	ND	--
12	<0.1	ND	ND	<0.1
13	<0.1	ND	<0.1	ND
15	<0.1	ND	<0.1	<0.1
18	<0.1	<0.1	<0.1	<0.1
21	<0.1	<0.1	<0.1	<0.1
23	<0.1	<0.1	<0.1	<0.1
27	--	--	<0.1	ND

[a] Using procedure described in Appendix D, compound has retention time of approximately 0.75 relative to hexachlorobenzene. Quantification based on hexachlorobenzene.

[b] NOT CORRECTED FOR EXTRACTION LOSSES

[c] Hydraulic data in Table 23.

ND = not detected

and 15/100 mL from HD 8x16. The effluent densities decreased with declining source water temperatures. At week 13, as the temperature dropped to 4°C (39°F), the GAC effluent coliform densities measured <1/100 mL from all three beds and remained at that density through week 32. During the entire study, total coliform density was measured daily in the effluent from one of five sand filtration beds at the utility sampled on a rotating basis. These coliform densities always measured <1/100 mL.

The standard plate count data for the first eleven weeks of the study also indicate greater bacterial densities in the GAC effluent than in the influent waters. While the mean GAC influent density was 190 bacteria/mL during weeks four through eleven, the mean effluent densities were: 9,400/mL from Filtrasorb 400; 26,000/mL from Filtrasorb C; and 19,000/mL from HD 8x16. A significant drop in the effluent standard plate count densities from all three beds occurred during weeks nine through eleven and beyond, as raw water temperatures declined below 10°C (50°F). From weeks 12 to 32, the influent and effluent densities were approximately the same.

Due to the apparent correlation in GAC effluent bacterial densities and raw water temperatures, the same three GAC beds were sampled when the raw water temperatures were again in excess of 10°C. Data presented in Table 30

TABLE 30. WATER QUALITY DATA BEAVER FALLS AUTHORITY SEPTEMBER 1978-DECEMBER 1978

Week of Operation	Raw		GAC Influent (Settled)		GAC Effluent					
					Filtrasorb 400		Filtrasorb C		HD 8x16	
	Temp, °C	TC[a]	Free Chlorine[b]	TC[a]	Free Chlorine[b]	TC[a]	Free Chlorine[b]	TC[a]	Free Chlorine[b]	TC[a]
53	26	18,000	1.4	<1	TR	100	TR	64	TR	130
54	23	10,000	1.2	<1	TR	120	TR	25	TR	240
55	22	22,000	1.6	<1	TR	230	TR	21	TR	730
56	19	9,200	1.6	<1	TR	470	TR	5	TR	330
57	14	31,000	1.4	<1	TR	62	TR	9	TR	82
58	12	10,000	1.1	<1	TR	44	TR	10	TR	55
59	14	8,700	1.4	<1	TR	30	TR	3	TR	31
60	13	19,000	1.3	<1	TR	8	TR	<1	TR	9
61	11	5,000	1.5	<1	TR	--	TR	2	TR	<1
62	9	12,000	0.8	<1	TR	1	TR	<1	TR	<1
63	8	82,000	1.2	<1	TR	<1	TR	<1	TR	<1
64	6	8,000	1.0	<1	TR	<1	TR	<1	TR	<1

[a] Total coliform/100 mL
[b] Chlorine, mg/L
TR = trace

indicate that effluent total coliform densities from all three GAC beds again exceeded influent densities of <1/100 mL when temperatures were above 10°C. As the temperatures dropped below 10°C, effluent total coliform densities from all three GAC beds measured <1/100 mL.

Rate of reproduction of bacteria in the GAC beds was the probable cause of higher GAC effluent bacterial densities when temperatures exceeded 10°C. Other conditions that may have favored growth on the GAC were the reduction of free chlorine, the large surface area, and the possible accumulation of nutrients.

Finished water quality was adequately maintained during the study at a total coliform density of <1/100 mL and a standard plate count density of <500/mL with the application of chlorine following GAC adsorption/filtration.

Findings--

1. Trihalomethane formation occurred during treatment following chlorine application and generally varied with water temperature.

2. Virgin GAC receiving chlorinated, settled water and operating in the filtration/adsorption mode in beds designed for sand filtration during warmer months was exhausted for the removal of:

	Weeks to Exhaustion		
	Filtrasorb 400	Filtrasorb C	Hydrodarco 8x16
Chloroform	9 - 10	12 - 15	8 - 10
Bromodichloromethane	8 - 10	12 - 15	8 - 10
Dibromochloromethane	10 - 14	14 - 15	8 - 10
Inst TTHM	9 - 10	12 - 15	8 - 10
THMFP	12	12	11

3. When breakpoint chlorination was discontinued, resulting in significant reduction of GAC influent trihalomethane concentrations, five-month-old GACs desorbed trihalomethanes.

4. GACs operated in the filtration/adsorption mode in beds designed for sand filtration:

a. passed carbon tetrachloride at concentrations (0.1-0.3 ug/L) that could not be differentiated from influent concentrations after seven months of operation.

b. passed 1,4-dichlorobenzene at concentrations that could not be differentiated from influent concentrations after three months of operation.

5. With temperatures in excess of 10°C, total coliform densities and standard plate count densities in GAC effluent waters greatly exceeded densities in GAC influent waters.

6. The bacterial quality of the finished water was satisfactory with clear well chlorination.

CONCLUSIONS FROM TRIHALOMETHANE TREATABILITY STUDIES

1. A change in the chlorine application point to a better quality water was a viable approach to trihalomethane control.

2. Moving the point of chlorine application resulted in lower finished water instantaneous trihalomethanes because a better quality water in terms of reduced THMFP was chlorinated and/or because in-plant THM reaction time was reduced.

3. The use of chlorine dioxide as an alternative disinfectant to chlorine was a viable approach to trihalomethane control.

4. Ammoniation was a viable approach to trihalomethane control.

5. Relatively higher concentrations of brominated THMs resulted in finished water when the in-plant reaction time with free chlorine was reduced.

6. Granular activated carbon was effective for trihalomethane control for short periods of time but would not be effective for long periods of time without reactivation.

7. The extent to which a utility can lower its trihalomethane levels will depend on its physical plant, its adaptability to these and other changes in treatment, and its financial capability.

8. Any modification to treatment should not be evaluated by instantaneous trihalomethane concentrations alone. Terminal trihalomethane concentrations and THMFP can define the changing levels of precursor in raw water and can define the effects of treatment on precursor levels. An understanding of precursor is necessary for an evaluation of the modification.

9. Raw water precursor levels, as measured by terminal level trihalomethane concentrations, can vary significantly over short periods of time. A better evaluation of changing levels of raw water precursor and of the effects of treatment on precursor levels will be made as the number of instantaneous and terminal level trihalomethane samples increases.

10. Treatment modifications should not be evaluated without monitoring the bacterial quality of in-plant and finished waters.

11. Any modification to treatment should be studied over a long period of time. Seasonal effects in bacterial densities and trihalomethane formation should be evaluated. Changes in raw water precursor levels should be evaluated. Other changes in water quality may affect results.

12. The effect of PAC, permanganate or chlorine dioxide on precursor could not be determined because raw water precursor levels varied significantly over a short time period, feed of these materials preceeded coagulation and

settling, and settling normally reduced precursor levels.

13. Reduction in terminal TTHM concentrations generally coincided with reduction in turbidity levels.

SECTION 7

ORGANIC COMPOUND SURVEY

GENERAL

Project activities included sampling for analysis for selected organic Priority Pollutants in raw and finished waters at all project utilities once a month from July 1977 to June 1978. In-plant waters were not sampled as a part of this survey. Raw and finished waters were sampled following theoretical plug flow through the plant. Although the raw and finished waters at a given utility could be compared, similar comparisons between utilities were of limited value.

Schematic treatment diagrams representative of routine treatment at the project utilities during the sample year are given in Figures 12, 14, 16, 18, 23, 29 and 33 in Section 6 and Figures 40 to 43 in this section. Although those diagrams presented in Section 6 are representative of treatment at the time trihalomethane control studies were conducted, they also describe treatment representative of the sample year.

All utilities treating surface waters practiced chlorination. The reaction between chlorine and precursor, discussed in Section 6, resulted in trihalomethane formation during treatment at these utilities. The extent of trihalomethane formation at each utility depended upon its treatment processes, pH levels, chlorine feed rates, ammonia levels, in-plant THM reaction time, etc.

SURVEY FOR PURGEABLE HALOCARBONS

Discussion of purgeable halocarbons is based on GC/Hall and GC/MS analyses of project samples and on accumulated purgeable halocarbon quality assurance data (Appendix C). The following discussions are based on the quality assurance procedures and methods of interpretation discussed in Section 5.

Chloroform (Raw water data: Table 32. Finished water data: Tables 33 and 34. Quality assurance data: Table C-1 and Figures C-1 and C-2.)

Chloroform was detected in 139 of 198 raw water samples and in 169 of 170 finished water samples. Mean raw water chloroform concentration, when detected, was 0.8 ug/L. Mean annual finished water chloroform concentration was 35 ug/L for treated surface waters and 0.9 ug/L for West View's treated ground water.

Chloroform was found in 100% of chlorinated surface waters. Finished

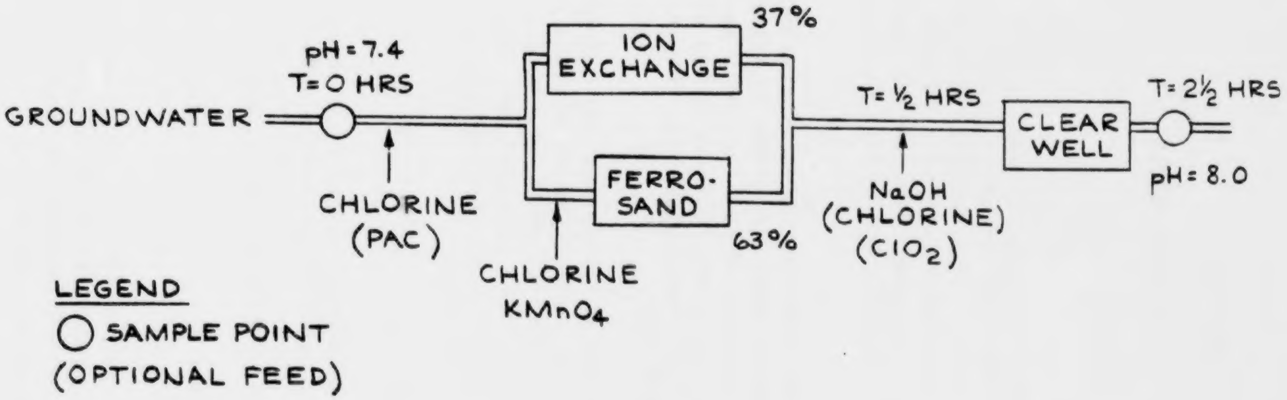


Figure 40. Treatment at West View Water Authority, 57,000 cu m/day (15 MGD).

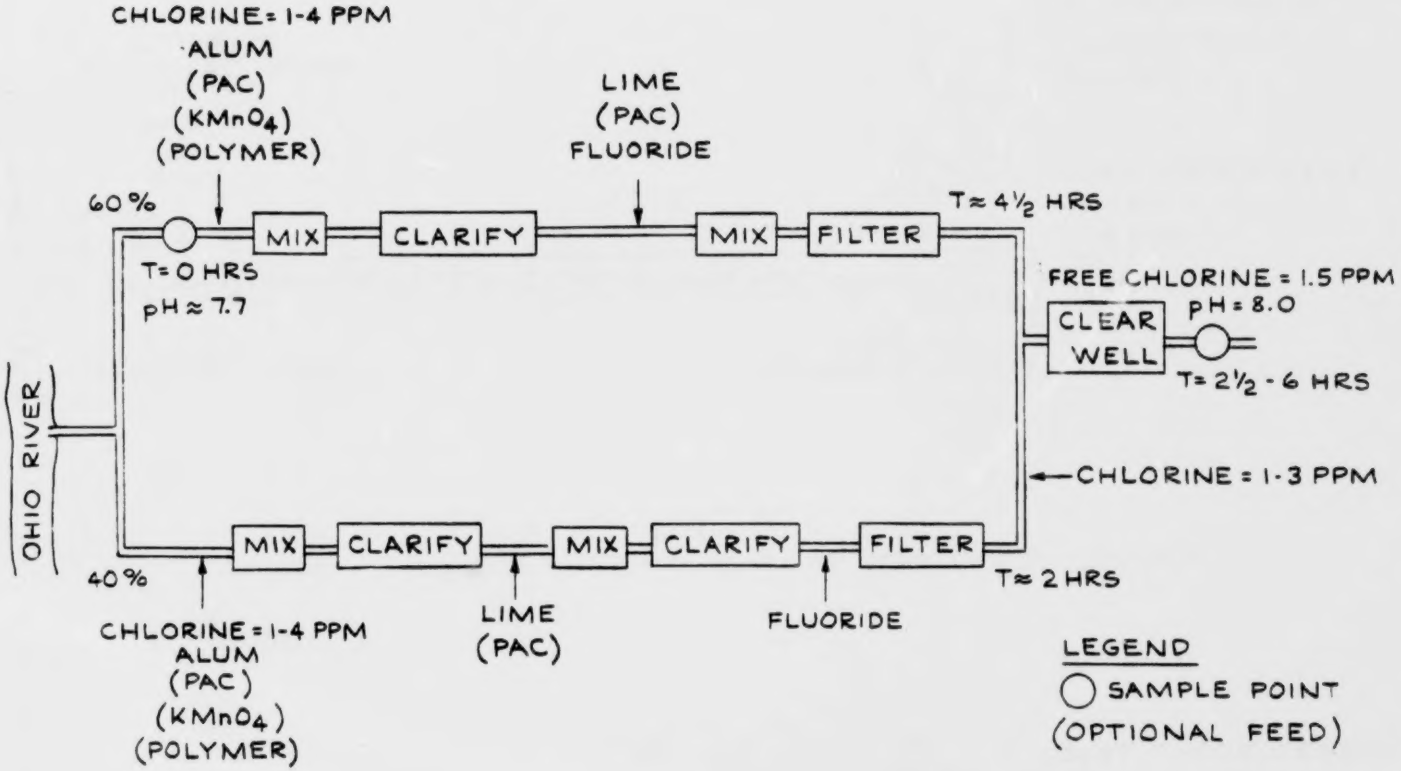


Figure 41. Treatment at Evansville Water Department, 99,000 cu m/day (26 MGD).

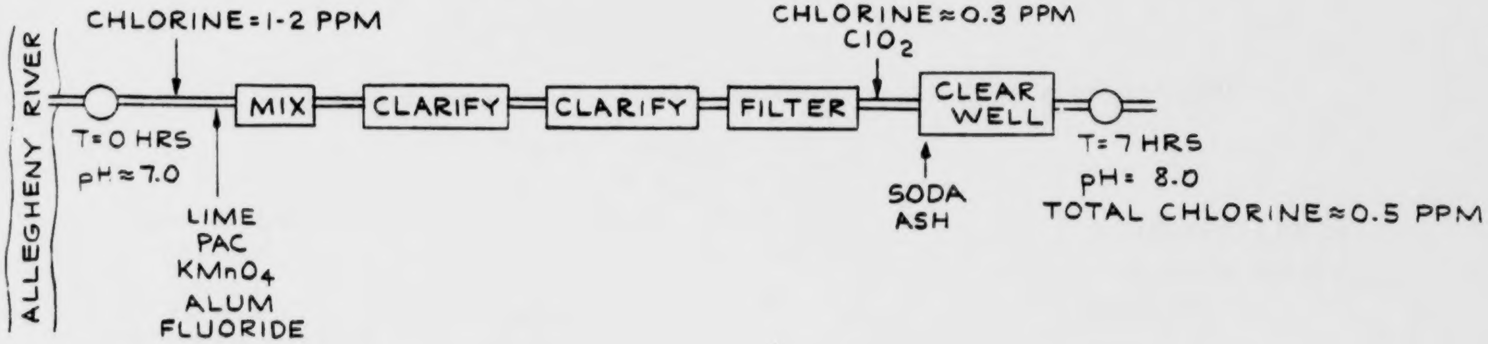


Figure 42. Treatment at Fox Chapel Authority, 6,800 cu m/day (1.8 MGD).

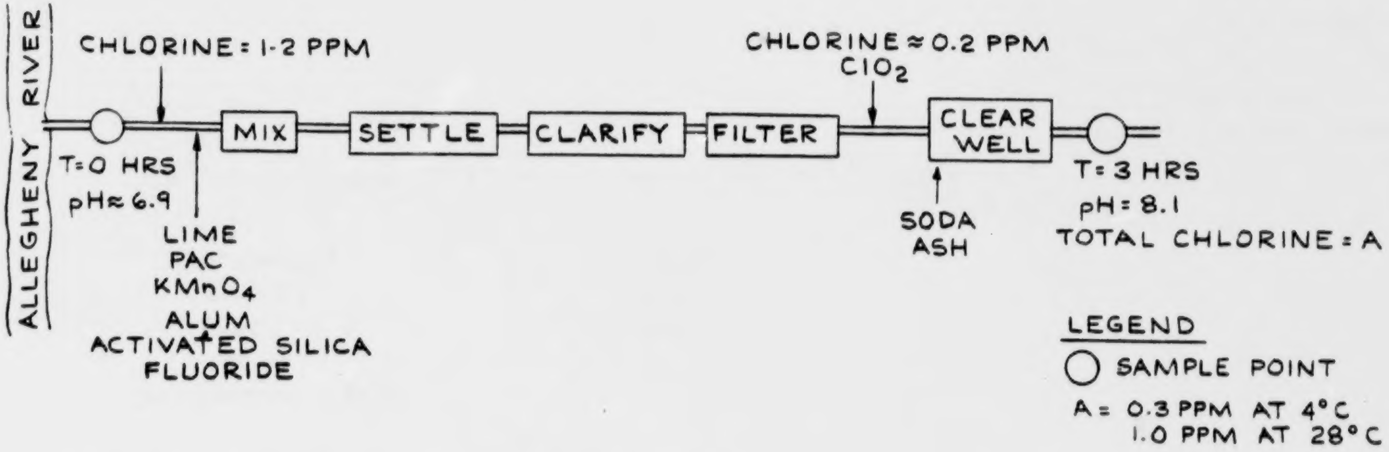


Figure 43. Treatment at Wilkinsburg-Penn Joint Water Authority, 95,000 cu m/day (25 MGD).

water chloroform concentrations were typically lower at utilities attempting to minimize chlorine feed rates, i.e., Wilkinsburg, and typically higher at utilities carrying finished water free chlorine residuals at or above 1.5 ug/L, i.e., Wheeling, Louisville or Evansville. Finished water chloroform concentrations were typically higher where finished water pH was high, i.e., Wheeling. Finished water chloroform concentrations were lower in the coldest months of the year and higher in the warmest months of the year. When West View's ground water was chlorinated, trihalomethane formation did not exceed 1.2 ug/L and no seasonal pattern was apparent.

Chloroform levels reaching the consumer will be higher than levels presented in Tables 33 and 34 if a free chlorine residual persists in the distribution system.

Bromodichloromethane (Raw water data: Table 35. Finished water data: Tables 36 and 37. Quality assurance data: Table C-2 and Figure C-4.)

Bromodichloromethane was detected in 84 of 200 raw water samples and in all 170 finished water samples. The mean raw water bromodichloromethane concentration, when detected, was 0.3 ug/L. The mean annual finished water bromodichloromethane concentration was 13 ug/L for treated surface waters and 0.4 ug/L for treated ground water. As with chloroform, the formation of bromodichloromethane resulted from in-plant chlorination, varied with seasonal temperature (except for the ground water) and was different for each utility's treatment.

Dibromochloromethane (Raw water data: Table 38. Finished water data: Tables 39 and 40. Quality assurance data: Table C-3 and Figure C-6.)

Dibromochloromethane was detected in 33 of 200 raw waters and in 168 of 170 finished waters. Mean raw water concentration, when detected, was 0.2 ug/L. Mean annual finished water concentration was 5.6 ug/L for treated surface waters and 0.3 ug/L for treated ground water. As with chloroform, the formation of dibromochloromethane resulted from in-plant chlorination, varied with seasonal temperature (except for ground water) and was different for each utility's treatment.

Bromoform (Raw water data: Table 41. Finished water data: Tables 42 and 43. Quality assurance data: Table C-4 and Figure C-9.)

Bromoform was detected in 8 of 200 raw waters and in 114 of 170 finished waters. Raw water concentrations did not exceed 0.1 ug/L. Finished water concentrations, when detected, averaged 0.8 ug/L in treated surface waters and 0.1 ug/L in treated ground water. As with chloroform, the formation of bromoform resulted from in-plant chlorination, varied with seasonal temperature (except for ground water) and was different for each utility's treatment.

Dichloroiodomethane (Raw water data: Table 44. Finished water data: Tables 45 and 46. Quality assurance data: Table C-6.)

Dichloroiodomethane was rarely detected (frequency = 1/200) in raw water and was detected in 81 of 170 finished water samples. Raw water concentrations did not exceed 0.1 ug/L. Finished water concentrations, when detected, averaged 0.2 ug/L in treated surface waters and were less than 0.1 ug/L in treated ground water. As with chloroform, the formation of dichloroiodomethane resulted from in-plant chlorination and generally varied with seasonal temperature (except for ground water). Because the precision of dichloroiodomethane data below 0.2 ug/L may be ± 100%, caution is suggested in concluding that this compound was absent in Evansville's waters or that it occurred infrequently in other utility waters.

Total Trihalomethane (Finished water data: Table 47. Quality assurance data: Figure C-11.)

As with the individual trihalomethane compounds, finished water TTHM concentrations varied with seasonal temperatures and were different for each utility's treatment. The seasonal trend was not apparent at West View where ground water is chlorinated. TTHM levels reaching the consumer will be higher than the levels presented in Table 46 if a free chlorine residual persists in the distribution system because finished waters contain trihalomethane formation potential.

Trihalomethane Formation Potential (THMFP)

Once a month, or more frequently if THM control studies were conducted, waters were sampled for analysis of instantaneous level THMs and terminal level THMs. Instantaneous level THM data are presented in Tables 32 through 47. As explained in Section 4, pages 11 and 12, terminal level THM data can be used to evaluate precursor levels. Such data for raw and finished water, then, allow the evaluation of THM formation and reduction of precursor levels in-plant, as shown in Tables 48 through 57.

Table 48 presents these data for Huntington. In July, for example, at Huntington, the raw water mean terminal TTHM concentration for several sample days was 327 ug/L. Because the mean instantaneous TTHM concentration was <1 ug/L, the mean raw water THMFP was 326 ug/L. Finished water mean concentrations were 232 ug/L terminal, 112 ug/L instantaneous and 120 ug/L THMFP. Thus, treatment affected raw water THMFP, or raw water unreacted precursor, in several ways. Chlorine reacted to form 112 ug/L TTHM, accounting for 34% of the raw water THMFP. Treatment, principally coagulation and settling, removed 29% of the raw water THMFP. Thus, 37% of the raw water THMFP remained after treatment and had the potential to form an additional 120 ug/L TTHM in the distribution system.

Less than 120 ug/L TTHM may have been formed in the distribution system because system detention time was less than the seven-day storage period for the terminal level parameter, distribution system free chlorine residuals were less than the 15 mg/L free chlorine added to drive the THM reaction during the storage period, and storage conditions for determination of the terminal level parameter (headspace free in clean glassware) are unlike distribution system conduit and storage tanks. Nevertheless, the finished water had the potential to form further THMs in the distribution system.

When these Huntington data were evaluated over a one-year period, they indicated that 30% of the raw water precursor formed TTHM, 29% of the precursor was removed by treatment, and 41% entered the distribution system with the potential for further THM formation.

Averaging data from the ten utilities treating surface water indicated that 23% of the raw water THMFP was converted to TTHM during treatment, 37% of the raw water THMFP was removed by treatment, and 40% of the raw water THMFP was discharged to the distribution system. Thus, trihalomethane formation will continue in the distribution system if a free chlorine residual is present.

Such percentages are presented in an attempt to evaluate treatment. The significance of these percentages cannot be defined. It is known that the expected variability of an instantaneous TTHM concentration may be ± 20% (Figure C-11) and that the expected variability of a terminal TTHM concentration may be ± 16% (Figure C-12), but the expected variability of the difference of these, i.e., THMFP, or a ratio of these, i.e., percentage, cannot be defined.

Comparison of these data for several utilities should be made cautiously for several reasons: chlorine application rates can vary from month to month within a utility and do vary among utilities; in-plant THM reaction times vary among utilities; coagulants and their effectiveness vary among utilities; pH varies among utilities, etc.; the significance of such data cannot be defined.

Raw water THMFP concentrations were evaluated to determine if precursor varied seasonally. Because the storage temperature of samples for determination of the terminal level TTHM was at or near the finished water temperature, it was expected that raw water THMFP concentrations would be lowest when water temperatures were coldest. For all ten utilities, Figure 44 presents monthly mean storage temperature data and raw water THMFP concentrations plotted against time. Initially, terminal level samples were stored at room temperature. When water temperature began falling, terminal level samples were stored at or near finished water temperature. Figure 44 presents mean storage temperature and mean raw water temperature for the initial months of the study.

These data indicate that from October through June, temperature and raw water THMFP concentrations generally varied in the same direction. However, from August through October, raw water THMFP concentrations increased while storage temperatures remained constant and raw water temperature decreased. This suggests that precursor levels were higher between August and October than at other times of the year.

Seasonal variation in raw water THMFP data and data for the fate of raw water THMFP are not presented for West View's ground water. These data were highly variable both in the terminal TTHM concentrations formed and in the amounts of chlorine consumed during storage for determination of this parameter. Finished water instantaneous TTHM concentrations for this utility, however, demonstrate that the ground water precursor differed from the surface water precursor because West View finished water total trihalomethanes never exceeded 2 ug/L.

Carbon Tetrachloride (Raw water data: Table 58. Finished water data: Table 59. Quality assurance data: Table C-5 and Figure C-8.)

With one exception, carbon tetrachloride was not detected in untreated surface waters upstream from Huntington. The frequency of detecting carbon tetrachloride in untreated surface waters was highest at Huntington and decreased with increasing distance downstream. On one occasion, the compound was GC/MS confirmed in the Allegheny River.

In another ORSANCO project utilizing the same analytical procedure and laboratory, carbon tetrachloride was present at 83% frequency in the Kanawha River at concentrations up to 1.9 ug/L.[19]

Carbon tetrachloride was occasionally detected in finished waters at all utilities except in treated ground water at West View. The presence of this compound in finished waters may be attributed to low level carbon tetrachloride contamination of chlorine used for disinfection. Periodic chlorine contamination is suggested by one-time finished water carbon tetrachloride concentrations at Louisville and Evansville of 1.3 ug/L and 6 ug/L, respectively.

At Huntington, finished water carbon tetrachloride levels were significantly higher than levels found in untreated surface water, i.e., the precision of the data indicates that the levels could not be the same. In addition to the possibility of carbon tetrachloride contamination of the chlorine supply, the increase was attributed to desorption of carbon tetrachloride from the one to two-year-old GAC filter/adsorbers in place at the utility (Section 6, Table 22). Carbon tetrachloride was detected 47% of the time (23/49) in Huntington's raw water but was detected 100% of the time in its finished water.

Chlorobenzene (Raw water data: Table 60. Finished water data: Table 61. Quality assurance data: Table C-7.)

The presence of chlorobenzene was GC/MS confirmed in untreated surface waters at Huntington and in untreated ground waters at West View. Accompanying finished waters at both locations also contained chlorobenzene. The frequency and concentrations of the data at Huntington are similar for raw and finished waters. At West View, however, all nine finished water samples contained chlorobenzene, while it was detected in only five of eleven raw water samples. The reason for the difference in frequency of data in raw and finished waters is not known.

In late March and early April 1978, Louisville was asked by project staff to increase once-a-month sampling frequency when ORSANCO was notified of a chlorobenzene spill. The resultant data (Table 31) indicate that chlorobenzene concentrations reached 8.5 ug/L in the finished water and suggest that conventional treatment at Louisville (raw water chlorination, settling, PAC, filtration and post-chlorination) was not effective for chlorobenzene removal.

1,1-Dichloroethane (Raw water data: Table 62. Finished water data: Table 63. Quality assurance data: Table C-8.)

TABLE 31. CHLOROBENZENE LEVELS, LOUISVILLE WATER COMPANY[a]

day	time	chlorobenzene,[b] ug/L raw water	chlorobenzene,[b] ug/L finished water
March 29	afternoon	0.8	--
March 30	morning	1.6	1.1
March 31	morning	5.0	2.5
March 31	afternoon	2.1	8.5
April 1	morning	0.1	5.3

[a] Plant detention time typically 30 hours

[b] GC/Hall detector, approximate lower detection level 0.1 ug/L

The presence of 1,1-dichloroethane was presumptively reported at several utility locations in both raw and finished waters at concentrations less than 1.0 ug/L. Its presence was GC/MS confirmed only in raw water at Wilkinsburg on one occasion and in raw and finished ground water at West View. There was no significant difference in the frequency and concentration of 1,1-dichloroethane for raw and finished water at West View.

1,2-Dichloroethane (Raw water data: Table 64. Finished water data: Table 65. Quality assurance data: Tables C-9 and C-10.)

1,2-dichloroethane was detected in the raw waters of eight project utilities with the frequency of detection increasing at and downstream from Huntington. The presence of 1,2-dichloroethane was GC/MS confirmed in raw waters at seven of those utilities. In finished waters, 1,2-dichloroethane was detected at four utilities only and GC/MS confirmed at two of those locations.

Review of project data for 1,2-dichloroethane indicated that the presence of large chloroform peaks eluting immediately ahead of this compound in project samples interfered with both its detection and quantification. The concentrations of 1,2-dichloroethane when found in raw waters were typically at or below 0.5 ug/L. Chloroform concentrations in raw water were typically at or below 1.0 ug/L and thus did not cause interference. In chlorinated waters, however, where chloroform concentrations were much higher and where 1,2-dichloroethane was found in the accompanying raw water, the compound was not detected. The chromatograms gave the visual appearance of a small deviation in the smooth tailing edge of the chloroform peak, a deviation that had insufficient slope change to cause integration (qualification and quantification). The difference in frequency of detection of 1,2-dichloroethane in project raw and finished samples is likely related to such chloroform interferences.

1,2-Dichloropropane (Raw water data: Table 66. Finished water data: Table 67. Quality assurance data: Table C-11.)

1,2-dichloropropane was detected infrequently in raw water samples from seven project utilities; the presence was GC/MS confirmed at two of those locations. In finished water samples, 1,2-dichloropropane was detected infrequently at ten utilities and GC/MS confirmed at two of those locations. Concentrations in both raw and finished waters never exceeded 0.2 ug/L.

trans-1,3-Dichloropropene (Raw water data: Table 68. Finished water data: Table 69. Quality assurance data: Table C-12.)

Trans-1,3-dichloropropene was detected only once and was of insufficient concentration for GC/MS confirmation. The compound was not found in project raw or finished waters at concentrations above 0.1 ug/L.

cis-1,3-Dichloropropene and/or 1,1,2-Trichloroethane

The compounds cis-1,3-dichloropropene and 1,1,2-trichloroethane co-elute with dibromochloromethane. Data presented in Table 37 indicate that detection at 0.1 ug/L of the co-eluters was infrequent in untreated surface waters and concentrations never exceeded 0.7 ug/L. GC/MS confirmation attempts for dibromochloromethane in untreated surface water were positive. One GC/MS confirmation attempt for cis-1,3-dichloropropene in untreated surface water proved negative.

The co-eluting compounds were detected in all chlorinated, finished surface water samples (Table 38), lending support to the presence of the dibromochloromethane. GC/MS confirmation attempts for dibromochloromethane in finished surface waters were positive; whereas, GC/MS confirmation attempts for cis-1,3-dichloropropene and 1,1,2-trichloroethane in finished surface waters were negative. It is believed that cis-1,3-dichloropropene and/or 1,1,2-trichloroethane rarely occurred in raw and finished surface waters.

Cis-1,3-dichloropropene and/or 1,1,2-trichloroethane were presumptively identified on two occasions in untreated and finished ground water at West View. GC/MS confirmation was not possible.

1,1,1-Trichloroethane, Trichloroethylene, and 1,1,2,2-Tetrachloroethane and/or Tetrachloroethylene (Quality assurance data: Tables C-13 to C-15.)

Constantly occurring interferences in all system blanks and project samples were apparent at the relative retention times of 1,1,1-trichloroethane, trichloroethylene, and 1,1,2,2-tetrachloroethane and/or tetrachloroethylene (Figure 4 and 5), and were GC/MS confirmed as being those compounds. An extensive investigation was conducted by the laboratory to determine the source of contamination and to eliminate or control it at acceptable concentrations. It was determined that laboratory air was probably the source of contamination. System exposure to laboratory air was minimized and the concentrations of contaminants were reduced.

The concentrations of contamination in system blanks were evaluated over a period of occurrence and statistically weighted (mean concentration plus two standard deviations) to reflect the interference for that period. This statistical correction was then subtracted from all sample data produced during that period. When the level of interference in a daily system blank exceeded the statistical correction, the daily blank correction was subtracted from all sample data produced that day.

A review of the resulting data after blank correction led to the conclusion that the presence of these compounds in project samples could not be reported. The resulting data reflected the highly variable nature of the contaminants and may have falsely suggested the absence of a compound. Thus, while the GC/Hall detection levels of these compounds were approximately 0.1 ug/L, they could not be reported below the following: 2.6 ug/L for 1,1,1-trichloroethane, 1.9 ug/L for trichloroethylene, and 3.4 ug/L for 1,1,2,2-tetrachloroethane and/or tetrachloroethylene. It is likely that these compounds were not present in project raw or finished waters above those concentrations. However, as mentioned in Section 6, page , high tetrachloroethylene concentrations (up to 60 ug/L) were observed and GC/MS confirmed in the Allegheny River. (Text continues on page 159.)

TABLE 32. CHLOROFORM RAW WATER DATA, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	11	5	1	0.2	0.9	1	1				
Wilkinsburg	12	4	1	0.3	0.7	1	1				
Pittsburgh	11	7	1	1.3	4.2						
WPW/Hays Mine[b]	6	5	1	2.1	4.8						
West View[c]	11	1	1	0.4	0.4						
Beaver Falls	29	25	1	0.3	0.7	1	1				
Wheeling	8	5	1	0.4	0.6						
Huntington	49	38	3	1.3	4.6	2	2				
Cincinnati	17	14	0	0.5	2.5						
Louisville	22	13	0	0.4	0.8	2	2				
Evansville	11	10	0	1.0	3.4	2	2				
Total or Mean	187	127	10	0.8	4.8	9	9				
West View[d]	11	2	0	1.1	1.5						

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply

TABLE 33. CHLOROFORM FINISHED[a] WATER DATA, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	12	12	0	8.1	29	1	1				
Wilkinsburg	12	12	0	8.3	25						
Pittsburgh	12	12	0	26	63	1	1				
WPW/Hays Mine[c]	11	11	0	18	51						
Beaver Falls	27	27	0	41	92						
Wheeling	11	11	0	59	120						
Huntington	24	24	0	42	180						
Cincinnati	19	19	0	35	76	1	1				
Louisville	21	21	0	51	100	2	2				
Evansville	12	12	0	60	86						
Total or Mean	161	161	0	35	180	5	5				
West View[d]	9	8	0	0.9	1.2						

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply

TABLE 34. FINISHED WATER[a] CHLOROFORM LEVELS 1977-1978 GC/HALL DETECTOR

Utility	Mean Concentration, ug/L												Annual Mean
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
Wilkinsburg[a]	8.2	25	22	14	5.6	3.2	1.6	1.4	2.4	2.1	6.1	6.4	8.3
Fox Chapel	3.7	29	29	11	2.4	1.2	1.4	1.4	2.7[+]	3.3	6.1	6.9	8.1
Pittsburgh[a]	38[+]	34	63	33	40	36	4.4	1.7	4.1	32	19	3.5	26
WPW/Hays Mine[b]	9.3	23	11	24	13	18	9.0	6.5	15	51	22	--	18
Beaver Falls	--	40	69	39	50	40	38	32[c]	6.5[d]	7.6	--	92	41
Wheeling	120	--	87	100	66	49	24	16	38	39	47	62	59
Huntington	38	78	62	46	26	22	--	15	20	40	51	59	42
Cincinnati	46[+]	49	62[e]	64[e]	20	22	26	9.1	20	26	27	52	35
Louisville	67[f]	85[g]	--	65[g]	77[+]	48	27	33	45	12	35	57	51
Evansville	33	82	86	86	70	61	36	17	39	58	71	84	60
West View[h]	ND	0.5	--	1.0	1.1	--	1.1	1.2	0.8	--	0.4	0.8	0.8

a = Clear well sample
b = Western Pennsylvania Water Co./Hays Mine Plant
c = February 1-15
d = February 21-March 31
e = Normal operation only. Not representative of treatment modification reported in Section 6.
f = MS confirmed in one sample. Others not MS attempted.
g = Treatment modification reported in Section 6.
h = Ground water supply
+ = MS confirmed
--No data available
ND = not detected

TABLE 35. BROMODICHLOROMETHANE RAW WATER DATA, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	11	0	3								
Wilkinsburg	12	0	1					1	1		
Pittsburgh	11	3	7	0.9	1.6						
WPW/Hays Mine[b]	8	1	0	0.1	0.1						
West View[c]	11	0	0								
Beaver Falls	29	3	12	0.1	0.2			1	0		
Wheeling	8	0	3								
Huntington	49	14	11	0.3	0.7	1	1	1	1		
Cincinnati	17	3	4	0.2	0.2			1	0		
Louisville	22	4	6	0.2	0.4						
Evansville	11	3	3	0.2	0.5	1	1	1	1		
Total or Mean	189	31	50	0.3	1.6	2	2	5	3		
West View[d]	11	1	2	0.2	0.2						

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Flant
c = Ohio River at West View
d = Ground water supply

TABLE 36. BROMODICHLOROMETHANE FINISHED[a] WATER DATA, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	12	12	0	2.9	12						
Wilkinsburg	12	12	0	3.6	10						
Pittsburgh	12	12	0	13	27	1	1				
WPW/Hays Mine[c]	11	11	0	6.2	14						
Beaver Falls	27	27	0	14	29	2	2				
Wheeling	11	11	0	13	33						
Huntington	24	24	0	17	44						
Cincinnati	19	19	0	18	42	1	1				
Louisville	21	21	0	19	48	1	1				
Evansville	12	12	0	22	54						
Total or Mean	161	161	0	13	59	5	5				
West View[d]	9	9	0	0.4	0.8						

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply

TABLE 37. FINISHED WATER[a] BROMODICHLOROMETHANE LEVELS 1977-1978 GC/HALL DETECTOR

Utility	Mean Concentration, ug/L												Annual Mean
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
Fox Chapel	3.5	12	7.9	3.2	0.7	0.3	0.6	0.8	0.7	0.8	1.7	3.1	2.9
Wilkinsburg[a]	5.9	10	7.6	5.4	1.7	1.9	1.5	0.9	1.4	0.7	2.4	3.3	3.6
Pittsburgh[a]	16[+]	26	27	20	16	13	1.5	0.5	1.1	17	14	3.7	13
WPW/Hays Mine[b]	3.1	14	7.4	8.6	3.6	5.4	2.7	2.2	2.4	10	9.1	--	6.2
Beaver Falls	--	29	18	15	16[a]	11	11	10[c]	2.4[d]	3.1	--	26	14
Wheeling	33	--	33	22	14	4.3	2.9	2.6	3.6	7.0	10	14	13
Huntington	29	30	27	18	11	6.5	--	6.1	5.3	14	13	25	17
Cincinnati	36[+]	42	30[e]	30[e]	14	11	13	2.9	5.9	12	15	24	18
Louisville	40[f]	42[g]	--	23[g]	20	12	9.5	12	9.9	6.6	12	22	19
Evansville	35	54	27	29	25	9.7	8.5	6.8	13	13	14	24	22
West View[h]	0.4	0.1	--	0.4	0.6	--	0.8	0.5	0.4	--	0.4	0.4	0.4

a = Clear well sample
b = Western Pennsylvania Water Co./Hays Mine Plant
c = February 1-15
d = February 21-March 31
e = Normal operation only. Not representative of treatment modification reported in Section 6.
f = MS confirmed in one sample. Others not MS attempted.
g = Treatment modification reported in Section 6.
h = Ground water supply
+ = MS confirmed
--No data available
ND = not detected

TABLE 38. DIBROMOCHLOROMETHANE[a,b] RAW WATER DATA, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Utility[c]	Times Hall searched for	Times Hall found $\geq$0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when $\geq$0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall $\geq$0.1 ug/L	Times MS confirmed when Hall $\geq$0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	11	0	1								
Wilkinsburg	12	1	0	0.3	0.3						
Pittsburgh	11	2	2	0.4	0.7						
WPW/Hays Mine[d]	8	0	0								
West View[e]	11	0	0								
Beaver Falls	29	1	1	0.2	0.2						
Wheeling	8	0	0								
Huntington[f]	49	12	3	0.2	0.6	1	1				
Cincinnati	17	1	2	0.1	0.1						
Louisville	22	4	1	0.2	0.6	1	1			1	1
Evansville	11	1	0	0.3	0.3						
Total or Mean	189	22	10	0.2	0.7	2	2			1	1
West View[g]	11	2[h]	1	0.2[h]	0.3[h]						

a = Tabled GC/Hall data represents dibromochloromethane and/or cis-1,3-dichloropropene and/or 1,1,2-trichloroethane unless noted.
b = Tabled GC/MS data represents dibromochloromethane only.
c = See Figure 1.
d = Western Pennsylvania Water Co., Hays Mine Plant.
e = Ohio River at West View.
f = One time GC/MS confirmation for cis-1,3-dichloropropene proved negative.
g = Ground water supply.
h = cis-1,3-dichloropropene and/or 1,1,2-trichloroethane.

TABLE 39. DIBROMOCHLOROMETHANE[a,b] FINISHED WATER DATA, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/l
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/l

Utility[c]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	12	10	2	0.9	3.0						
Wilkinsburg	12	12	0	1.0	2.7						
Pittsburgh	12	12	0	6.5	16	1	1				
WPW/Hays Mine[d,e,f]	11	11	0	4.0	15						
Beaver Falls	27	27	0	4.6	13	2	2				
Wheeling	11	11	0	4.6	19						
Huntington[f]	24	24	0	9.4	25						
Cincinnati	19	19	0	11	26	1	1				
Louisville	21	21	0	7.2	33	1	1				
Evansville	12	12	0	6.7	24						
Total or Mean	161	159	2	5.6	33	5	5				
West View[g]	9	7[h]	0	0.3[h]	0.4[h]						

a = Tabled GC/Hall data represents dibromochloromethane and/or cis-1,3-dichloropropene and/or 1,1,2-trichloroethane unless noted.
b = Tabled GC/MS data represents dibromochloromethane only.
c = See Figure 1.
d = Western Pennsylvania Water Co., Hays Mine Plant.
e = One time GC/MS confirmation for cis-1,3-dichloropropene proved negative.
f = One time GC/MS confirmation for 1,1,2-trichloroethane proved negative.
g = Ground water supply.
h = Does not represent one time GC/Hall report of cis-1,3-dichloropropene and/or 1,1,2-trichloroethane at 0.5 ug/l.

TABLE 40. FINISHED WATER[a] DIBROMOCHLOROMETHANE LEVELS 1977-1978
GC/HALL DETECTOR

Utility	Mean Concentration, ug/L												Annual Mean
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
Fox Chapel	1.5	3.0	1.6	0.6	0.2	<0.1	0.1	0.2	<0.1	0.2	0.3	1.4	0.8
Wilkinsburg[a]	2.7	2.3	2.0	1.2	0.3	0.6	0.4	0.4	0.4	0.1	0.8	1.5	1.0
Pittsburgh[a]	9.2+	16	11	8.6	4.7	3.3	0.2	0.2	0.2	7.2	11	6.6	6.5
WPW/Hays Mine[b]	3.1	15	7.9	5.1	2.8	2.0	0.6	0.9	0.6	2.7	3.8	--	4.0
Beaver Falls	--	13	4.4	5.5	4.4[f]	2.6[f]	2.7	4.1[c]	0.6[d]	0.8	--	7.9	4.6
Wheeling	19	--	11	5.2	3.0	0.4	0.4	0.4	0.5	1.7	3.7	5.2	4.6
Huntington	25	20	14	6.8	6.0	2.5	--	2.8	2.3	7.6	3.7	13	9.4
Cincinnati	26+	24	17[e]	13[e]	7.3	4.9	5.5	0.8	3.3	6.2	6.6	13	11
Louisville	23[f]	20[g]	--	5.4[g]	3.2	1.3	3.2	4.0	2.2	4.5	3.9	8.7	7.2
Evansville	16	24	7.7	6.4	5.5	1.3	1.6	3.0	4.8	2.3	2.3	5.3	6.7
West View[h]	0.3	ND	--	ND	0.2	--	0.4	0.2	0.2	--	0.3	0.3	0.2

a = Clear well sample
b = Western Pennsylvania Water Co./Hays Mine Plant
c = February 1-15
d = February 21-March 31
e = Normal operation only. Not representative of treatment modification reported in Section 6.
f = MS confirmed in one sample. Others not MS attempted.
g = Treatment modification reported in Section 6.
h = Ground water supply
+ = MS confirmed
--No data available
ND = not detected

TABLE 41. BROMOFORM RAW WATER DATA, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/l	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	11	0	1								
Wilkinsburg	12	0	0								
Pittsburgh	11	1	1	0.1	0.1						
WPW/Hays Mine[b]	8	0	0								
West View[c]	11	0	0								
Beaver Falls	29	0	0								
Wheeling	8	0	0								
Huntington	49	0	0								
Cincinnati	17	0	4								
Louisville	22	0	0							2	2
Evansville	11	0	0								
Total or Mean	189	1	6	0.1	0.1					2	2
West View[d]	11	0	1								

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply

TABLE 42. BROMOFORM FINISHED[a] WATER DATA, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	12	1	0	0.2	0.2						
Wilkinsburg	12	0	1								
Pittsburgh	12	7	2	1.0	3.8	1	0				
WPW/Hays Mine[c]	11	7	2	1.0	3.1						
Beaver Falls	27	8	9	0.3	0.6	2	2			1	0
Wheeling	11	7	1	0.4	0.9						
Huntington	24	21	1	1.1	4.4						
Cincinnati	19	18	0	1.0	2.7	1	1				
Louisville	21	18	1	0.5	2.1	1	1				
Evansville	12	3	4	0.3	0.8						
Total or Mean	161	90	21	0.8	4.4	5	4			1	0
West View[d]	9	1	2	0.1	0.1						

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply

TABLE 43. FINISHED WATER[a] BROMOFORM LEVELS 1977-1978
GC/HALL DETECTOR

Utility	Mean Concentration, ug/L												Annual
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Mean
Fox Chapel	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	<0.1
Wilkinsburg[a]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<0.1	<0.1
Pittsburgh[a]	0.2[-]	0.7	0.4	0.3	<0.1	<0.1	ND	ND	ND	0.3	1.2	3.8	0.6
WPW/Hays Mine[b]	0.3	3.1	2.6	0.8	0.3	<0.1	ND	0.2	ND	<0.1	0.3	--	0.7
Beaver Falls	--	0.4	<0.1	0.3	0.1[f]	<0.1[f]	<0.1	0.4[c]	<0.1[d]	ND	--	0.5	0.2
Wheeling	0.9	--	0.6	0.2	0.1	ND	<0.1	ND	0.1	ND	0.2	0.3	0.2
Huntington	2.0	1.3	1.4	0.5	0.6	0.1	--	0.3	ND	0.5	<0.1	1.0	0.7
Cincinnati	2.1[+]	1.2	1.6[e]	0.8[e]	0.2	0.1	0.2	ND	0.4	0.4	0.2	0.7	0.6
Louisville	1.1	0.9[g]	--	0.2[g]	ND	<0.1	0.2	0.3	0.1	0.3	ND	0.3	0.3
Evansville	0.4	0.8	<0.1	<0.1	<0.1	ND	ND	0.1	ND	ND	ND	<0.1	0.1
West View[h]	ND	ND	--	ND	ND	--	<0.1	ND	0.1	--	<0.1	ND	<0.1

a = Clear well sample
b = Western Pennsylvania Water Co./Hays Mine Plant
c = February 1-15
d = February 21-March 31
e = Normal operation only. Not representative of treatment modification reported in Section 6.
f = MS confirmed in one sample. Others not MS attempted.
g = Treatment modification reported in Section 6.
h = Ground water supply
+ = MS confirmed
- = MS negative
--No data available
ND = not detected

TABLE 44. DICHLOROIDOMETHANE RAW WATER DATA*, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/l
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥ 0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥ 0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥ 0.1 ug/L	Times MS confirmed when Hall ≥ 0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	11	0	0								
Wilkinsburg	12	0	0								
Pittsburgh	11	0	0								
WPW/Hays Mine[b]	8	0	0								
West View[c]	11	0	0								
Beaver Falls	29	0	0								
Wheeling	8	0	1								
Huntington	49	0	0								
Cincinnati	17	0	0								
Louisville	22	0	0								
Evansville	11	0	0								
Total or Mean	189	0	1								
West View[d]	11	0	0								

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground waterssupply
*Quantification relative to 1,4-dichlorobutane.

TABLE 45. DICHLOROIDOMETHANE FINISHED[a] WATER DATA* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	12	1	2	0.2	0.2						
Wilkinsburg	12	1	1	0.1	0.1						
Pittsburgh	12	2	3	0.3	0.6			1	1		
WPW/Hays Mine[c]	11	2	6	0.2	0.5						
Beaver Falls	27	1	5	0.2	0.2						
Wheeling	11	7	3	0.3	1.0	2	2				
Huntington	24	11	9	0.2	0.4	1	1				
Cincinnati	19	3	2	0.1	0.1	1	1	1	0		
Louisville	21	4	13	0.4	1.0						
Evansville	12	0	0								
Total or Mean	161	32	44	0.2	1.0	4	4	2	1		
West View[d]	9	0	5	0				1	1		

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply
*Quantification relative to 1,4-dichlorobutane.

TABLE 46. FINISHED WATER^{a} DICHLOROIODOMETHANE LEVELS 1977-1978
GC/HALL DETECTOR

Utility	Mean Concentration, ug/L												Annual Mean
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
Fox Chapel	ND	0.1	ND	ND	ND	<0.1	ND	<0.1	ND	ND	ND	ND	<0.1
Wilkinsburg^{a}	ND	ND	<0.1	ND	ND	ND	ND	ND	ND	ND	ND	0.1	<0.1
Pittsburgh^{a}	0.1	0.6	ND	ND	ND	<0.1	ND	ND	ND	$<0.1^{+}$	<0.1	ND	<0.1
WPW/Hays Mine^{b}	<0.1	0.5	ND	0.2	<0.1	ND	<0.1	<0.1	ND	<0.1	0.1	--	<0.1
Beaver Falls	--	0.2	ND	ND	ND	<0.1	<0.1	ND^{c}	$<0.1^{d}$	ND	--	ND	<0.1
Wheeling	0.2	--	<0.1	0.1^{+}	0.1	<0.1	<0.1	ND	0.1^{+}	0.4	0.4	1.0	0.2
Huntington	<0.1	0.2	0.1	0.2	<0.1	<0.1	--	<0.1	ND	0.2	0.1	0.3^{+}	0.1
Cincinnati	ND	ND	ND^{e}	$<0.1^{f}_{e}$	ND	ND	ND	ND	ND	ND	ND	ND	<0.1
Louisville	<0.1	0.3^{g}	--	0.1^{g}	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1
Evansville	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
West View^{h}	ND	<0.1	--	ND	<0.1	--	<0.1	$<0.1^{+}$	ND	--	ND	<0.1	<0.1

a = Clear well sample
b = Western Pennsylvania Water Co./Hays Mine Plant
c = February 1-15
d = February 21-March 31
e = Normal operation only. Not representative of treatment modification reported in Section 6.
f = MS confirmed in one sample. Others not MS attempted.
g = Treatment modification reported in Section 6.
h = Ground water supply
+ = MS confirmed
--No data available
ND = not detected

TABLE 47. FINISHED WATER[a] TOTAL TRIHALOMETHANE LEVELS, 1977-1978, GC/HALL DETECTOR

Utility	Mean Concentration, ug/L												Annual Mean
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
Wilkinsburg[a]	17	27	32	21	8	6	4	3	4	3	9	11	13
Fox Chapel	9	44	39	15	3	2	2	2	3	4	8	12	12
Pittsburgh[a]	63	77	101	62	61	52	5	2	6	56	45	18	46
WPW/Hays Mine[b]	16	56	29	38	19	25	12	10	18	64	35	--	29
Beaver Falls	--	83	91	60	71	54	52	47[c]	10[d]	12	--	126	60
Wheeling	173	--	132	128	83	54	27	19	42	48	61	82	77
Huntington	94	129	106	72	44	31	--	24	28	62	68	98	69
Cincinnati	109	116	111[e]	106[e]	42	38	45	13	30	45	49	89	66
Louisville	129	149[f]	--	94[f]	100	61	40	49	57	23	51	87	76
Evansville	84	161	121	121	101	72	47	27	57	73	87	113	89
West View[g]	1	1	--	2	2	--	--	2	--	--	1	2	2

[a] Clear well sample
[b] Western Pennsylvania Water Co./Hays Mine Plant
[c] February 1-15
[d] February 21-March 31
[e] Normal operation only. Not representative of treatment modification reported in Section 6.
[f] Treatment modification reported in Section 6.
[g] Ground water supply
--No data available.

TABLE 48. TRIHALOMETHANE FORMATION POTENTIAL (THMFP) - GC/HALL DETECTOR
HUNTINGTON WATER CORPORATION 1977-1978

Month[a]	Storage[b]		Mean Concentration, ug/L				Fate of Raw Water THMFP		
			Raw[c]	Clear Well			% that formed inst TTHM B/A	% removed by treatment (A-C)/A	% remaining D/A
	Temp, °C	pH	THMFP A	inst TTHM B	term TTHM C	THMFP D=C-B			
Jul[d]	room	--	326	112	232	120	34	29	37
Aug[d]	room	--	355	89	286	197	25	19	56
Sep[d]	room	8.3	219	106	202	96	48	7.7	44
Oct[d]	room	8.3	--	63	215	152	--	--	--
Nov	9	8.4	140	44	130	86	32	7.1	61
Dec[d]	4	8.4	225	31	91	60	14	59	27
Jan	3	8.4	90	--	--	--	--	--	--
Feb	3	8.4	79	24	56	32	30	29	41
Mar	4	8.3	150	28	81	53	19	46	35
Apr	6	7.9	180	62	90	28	34	50	16
May	2	8.0	220	68	150	82	31	32	37
Jun	21	8.3	350	98	300	202	28	14	58
						mean	30	29	41

[a] one sample day per month.
[b] 15 mg/l chlorine added. 7-day storage.
[c] raw water inst TTHM ≤1 ug/L.
[d] mean of two to four sample days per month.
--data not available.

TABLE 49. TRIHALOMETHANE FORMATION POTENTIAL (THMFP) - GC/HALL DETECTOR
FOX CHAPEL AUTHORITY 1977-1978

Month[a]	Storage[b]		Mean Concentration, ug/L				Fate of Raw Water THMFP		
			Raw[c]	Clear Well			% that formed inst TTHM B/A	% removed by treatment (A-C)/A	% remaining D/A
	Temp, °C	pH	THMFP A	inst TTHM B	term TTHM C	THMFP D=C-B			
Jul	room	--	133	8.7	86	77	6.5	35	58
Aug	room	8.0	265	44	158	114	17	40	43
Sep	room	7.8	285	38	182	144	13	36	50
Oct	room	7.7	282	15	136	121	5.3	51	43
Nov	4	7.8	119	3.3	62	59	2.8	48	50
Dec	9	7.8	92	1.6	50	48	1.7	46	52
Jan	10	7.8	76	2.1	32	30	2.6	58	39
Feb	1	7.8	71	2.4	40	38	3.4	44	54
Mar	13	7.8	176	3.4	63	60	1.9	64	34
Apr	18	7.8	130	4.3	64	59	3.3	51	39
May	26	7.8	226	8.1	80	72	3.6	65	32
Jun	20	7.8	193	12	103	91	6.2	47	47
						mean	5.6	49	45

[a] one sample day per month.
[b] 15 mg/l chlorine added. 7-day storage.
[c] raw water inst TTHM $\leqslant 1$ ug/L.
--data not available.

TABLE 50. TRIHALOMETHANE FORMATION POTENTIAL (THMFP) - GC/HALL DETECTOR
WILKINSBURG-PENN JOINT WATER AUTHORITY 1977-1978

			Mean Concentration, ug/l				Fate of Raw Water THMFP		
	Storage[b]		Raw[c]	Clear Well			% that formed inst TTHM	% removed by treatment	% remaining
Month[a]	Temp, °C	pH	THMFP A	inst TTHM B	term TTHM C	THMFP D=C-B	B/A	(A-C)/A	D/A
Jul	room	--	--	17	110	93	--	--	--
Aug	room	8.0	160	37	120	83	23	25	52
Sep	room	8.0	303	32	165	133	10	46	44
Oct	room	8.0	216	21	172	151	10	20	70
Nov	6	8.0	171	7.6	97	90	4.4	43	53
Dec	4	8.0	134	5.8	68	62	4.3	49	46
Jan	2	8.1	--	3.5	70	66	--	--	--
Feb	4	8.1	76	2.3	42	39	3.7	45	51
Mar	4	7.8	124	4.2	68	64	3.4	45	52
Apr	10	8.1	126	2.8	78	75	2.2	38	60
May	16	8.1	170	9.3	99	90	5.5	42	53
Jun	24	8.1	255	11	195	184	4.3	24	72
						mean	7.1	38	55

[a] one sample day per month.
[b] 15 mg/l chlorine added. 7-day storage.
[c] raw water inst TTHM $\leqslant$1 ug/L.
--data not available.

TABLE 51. TRIHALOMETHANE FORMATION POTENTIAL (THMFP) - GC/HALL DETECTOR
PITTSBURGH DEPARTMENT OF WATER 1977-1978

Month[a]	Storage[b]		Mean Concentration, ug/L				Fate of Raw Water THMFP		
			Raw[c]	Clear Well			% that formed inst TTHM B/A	% removed by treatment (A-C)/A	% remaining D/A
	Temp, °C	pH	THMFP A	inst TTHM B	term TTHM C	THMFP D=C-B			
Jul	room	7.0	482	63	271	208	13	44	43
Aug	room	7.8	344	77	235	158	22	32	45
Sep	room	8.0	207	101	--	--	49	--	--
Oct	room	8.6	≥279	62	197	135	22	29	48
Nov	11	8.5	219	62	109	47	28	50	21
Dec	7	8.6	294	52	136	84	18	54	28
Jan	12	8.6	158	6.1	102	97	3.9	35	61
Feb	7	8.7	118	2.5	89	86	2.1	24	73
Mar	6	8.4	282	5.4	107	102	1.9	62	36
Apr	12	8.4	209	56	136	80	27	35	38
May	14	8.4	196	45	181	135	23	7.6	69
Jun	22	8.5	260	18	132	114	6.9	49	44
						mean	15	38	46

[a] one sample day per month.
[b] 15 mg/1 chlorine added. 7-day storage.
[c] raw water inst TTHM ≤1 ug/L.
-- data not available.

TABLE 52. TRIHALOMETHANE FORMATION POTENTIAL (THMFP) - GC/HALL DETECTOR
WESTERN PENNSYLVANIA WATER COMPANY (HAYS MINE PLANT) 1977-1978

	Storage[b]		Mean Concentration, ug/L				Fate of Raw Water THMFP		
			Raw[c]	Clear Well					
Month[a]	Temp, °C	pH	THMFP A	inst TTHM B	term TTHM C	THMFP D=C-B	% that formed inst TTHM B/A	% removed by treatment (A-C)/A	% remaining D/A
Jul	room	--	191	16	--	--	8.4	--	--
Aug	room	7.7	264	55	122	67	21	54	25
Sep	room	7.5	289	29	153	124	10	47	43
Oct	room	7.6	--	39	--	--	--	--	--
Nov	7	7.8	98	19	98	79	19	0	81
Dec	7	7.8	77	26	--	--	34	--	--
Jan	2	8.0	127	12	74	62	9.4	42	49
Feb	3	8.0	79	9.6	63	53	12	20	67
Mar	7	7.4	≥189	18	58	41	9.5	69	22
Apr	14	7.4	83	64	73	9	78	12	11
May	15	7.4	--	35	82	47	--	--	--
Jun[d]	--	--	--	--	--	--	--	--	--
						mean	23	35	42

[a] one sample day per month.
[b] 15 mg/l chlorine added. 7-day storage.
[c] raw water inst TTHM ≤1 ug/L.
[d] no samples collected.
--data not available.

TABLE 53. TRIHALOMETHANE FORMATION POTENTIAL (THMFP) - GC/HALL DETECTOR
BEAVER FALLS MUNICIPAL AUTHORITY 1977-1978

Month[a]	Storage[b]		Mean Concentration, ug/L				Fate of Raw Water THMFP		
			Raw[c]	Clear Well					
	Temp, °C	pH	THMFP A	inst TTHM B	term TTHM C	THMFP D=C-B	% that formed inst TTHM B/A	% removed by treatment (A-C)/A	% remaining D/A
Jul	room	--	143	--	--	--	--	--	--
Aug	room	7.5	180	83	150	67	46	17	37
Sep	room	7.3	383	84	178	94	22	53	25
Oct	room	7.2	$\geq$245	59	183	124	24	25	51
Nov[d]	10	7.4	268	70	226	156	26	16	58
Dec[d]	4	7.4	175	54	112	58	31	36	33
Jan	2	7.5	143	54	101	47	38	29	33
Feb 1-15[d]	22	7.2	119	47	94	47	39	21	40
Feb 21-Mar 31[d,e]	4	7.3	151	10	50	40	6.6	67	27
Apr[e]	11	7.2	138	11	80	69	8.0	42	50
May	16	7.4	--	--	--	--	--	--	--
Jun	21	7.5	189	126	136	10	67	28	5.3
						mean	31	33	36

[a] one sample day per month.
[b] 15 mg/l chlorine added. 7-day storage.
[c] raw water inst TTHM $\leq$1 ug/l.
[d] mean of two to four sample days per month.
[e] no breakpoint chlorination.
--data not available.

TABLE 54. TRIHALOMETHANE FORMATION POTENTIAL (THMFP) - GC/HALL DETECTOR
WHEELING WATER DEPARTMENT 1977-1978

			Mean Concentration, ug/L				Fate of Raw Water THMFP		
	Storage[b]		Raw[c]	Clear Well			% that formed inst TTHM B/A	% removed by treatment (A-C)/A	% remaining D/A
Month[a]	Temp, °C	pH	THMFP A	inst TTHM B	term TTHM C	THMFP D=C-B			
Jul	room	--	247	173	--	--	70	--	--
Aug	room	9.4	323	--	>391	--	--	-21	--
Sep	room	9.1	--	132	157	25	--	--	--
Oct	room	9.4	260	127	225	98	49	13	38
Nov	7	9.3	232	83	115	32	36	50	14
Dec	4	9.3	240	54	132	78	22	45	33
Jan	6	9.2	--	27	89	62	--	--	--
Feb	7	9.3	125	19	93	75	14	26	60
Mar	4	9.3	154	42	107	65	27	30	42
Apr	9	9.3	98	48	75	27	49	23	28
May	20	9.2	676	61	--	--	9.0	--	--
Jun	23	9.1	342	81	275	194	24	20	57
						mean	32	30	39

[a] one sample day per month.
[b] 15 mg/l chlorine added. 7-day storage.
[c] raw water inst TTHM $\leq$ 1 ug/L.
-- data not available.

TABLE 55. TRIHALOMETHANE FORMATION POTENTIAL (THMFP) - GC/HALL DETECTOR CINCINNATI WATER WORKS 1977-1978

Month[a]	Storage[b]		Mean Concentration, ug/L				Fate of Raw Water THMFP		
			Raw[c]	Clear Well					
	Temp, °C	pH	THMFP A	inst TTHM B	term TTHM C	THMFP D=C-B	% that formed inst TTHM B/A	% removed by treatment (A-C)/A	% remaining D/A
Jul	room	--	--	109	287	178	--	--	--
Aug	room	8.2	202	116	121	5	57	40	2.5
Sep	25	8.4	⩾305	111	165	54	36	46	18
Oct[d]	18	8.3	⩾508	106	338	232	21	33	46
Nov	17	8.2	⩾230	42	119	77	18	48	33
Dec	7	8.3	⩾321	38	98	60	12	69	19
Jan	7	8.2	194	45	89	45	23	54	23
Feb	2	8.3	125	13	61	48	10	51	38
Mar	4	8.4	266	30	83	54	11	69	20
Apr	16	8.5	--	45	115	70	--	--	--
May	18	8.5	373	49	133	84	13	64	22
Jun	24	8.1	⩾379	89	243	154	23	36	41
						mean	22	51	26

[a] one sample day per month.

[b] 15 mg/l chlorine added. 7-day storage.

[c] raw water inst TTHM ⩽1 ug/L.

[d] mean of two to four sample days per month.

--data not available.

TABLE 56. TRIHALOMETHANE FORMATION POTENTIAL (THMFP) - GC/HALL DETECTOR LOUISVILLE WATER COMPANY 1977-1978

			Mean Concentration, ug/L				Fate of Raw Water THMFP		
			Raw[c]	Clear Well					
	Storage[b]		THMFP A	inst TTHM B	term TTHM C	THMFP D=C-B	% that formed inst TTHM B/A	% removed by treatment (A-C)/A	% remaining D/A
Month[a]	Temp, °C	pH							
Jul[e]	room	--	339	129	316	187	38	6.8	55
Aug[e]	room	--	315	149	245	96	47	22	30
Sep[d]	--	--	--	--	--	--	--	--	--
Oct[e]	room	--	325	94	244	150	28	25	46
Nov	room	8.3	252	100	160	59	40	36	23
Dec	11	8.4	245	61	112	51	25	54	21
Jan	6	8.4	91	40	74	34	44	19	37
Feb	4	8.4	80	49	78	28	62	2.5	35
Mar	8	8.4	185	57	120	63	31	35	34
Apr	15	8.3	240	23	100	77	10	58	32
May	22	8.3	192	51	148	97	26	23	50
Jun	20	8.1	269	87	192	105	32	29	39
						mean	35	28	36

[a] one sample day per month.
[b] 15 mg/l chlorine added. 7-day storage.
[c] raw water inst TTHM $\leqslant$1 ug/L.
[d] no samples collected.
[e] mean of two to four sample days per month.
--data not available.

TABLE 57. TRIHALOMETHANE FORMATION POTENTIAL (THMFP) - GC/HALL DETECTOR
EVANSVILLE WATER DEPARTMENT 1977-1978

Month[a]	Storage[b]		Mean Concentration, ug/L				Fate of Raw Water THMFP		
			Raw[c]	Clear Well			% that formed inst TTHM B/A	% removed by treatment (A-C)/A	% remaining D/A
	Temp, °C	pH	THMFP A	inst TTHM B	term TTHM C	THMFP D=C-B			
Jul	room	--	285	84	259	175	29	9.1	61
Aug	room	7.8	324	161	218	57	35	33	18
Sep	room	7.9	437	121	308	187	28	29	43
Oct	room	8.2	≥573	121	--	--	21	---	--
Nov	12	8.1	266	100	147	47	38	45	18
Dec	4	8.1	248	71	112	41	29	55	16
Jan	<1	7.8	208	46	82	36	22	61	17
Feb	1	8.1	113	26	--	--	23	--	--
Mar	6	8.1	173	57	84	27	33	51	16
Apr	15	8.3	213	73	225	152	34	- 5.6	71
May	16	8.0	331	88	152	64	26	54	19
Jun	26	8.1	379	113	259	146	30	32	38
						mean	30	36	32

[a] one sample day per month.
[b] 15 mg/l chlorine added. 7-day storage.
[c] raw water inst TTHM ≤1 ug/L.
--data not available.

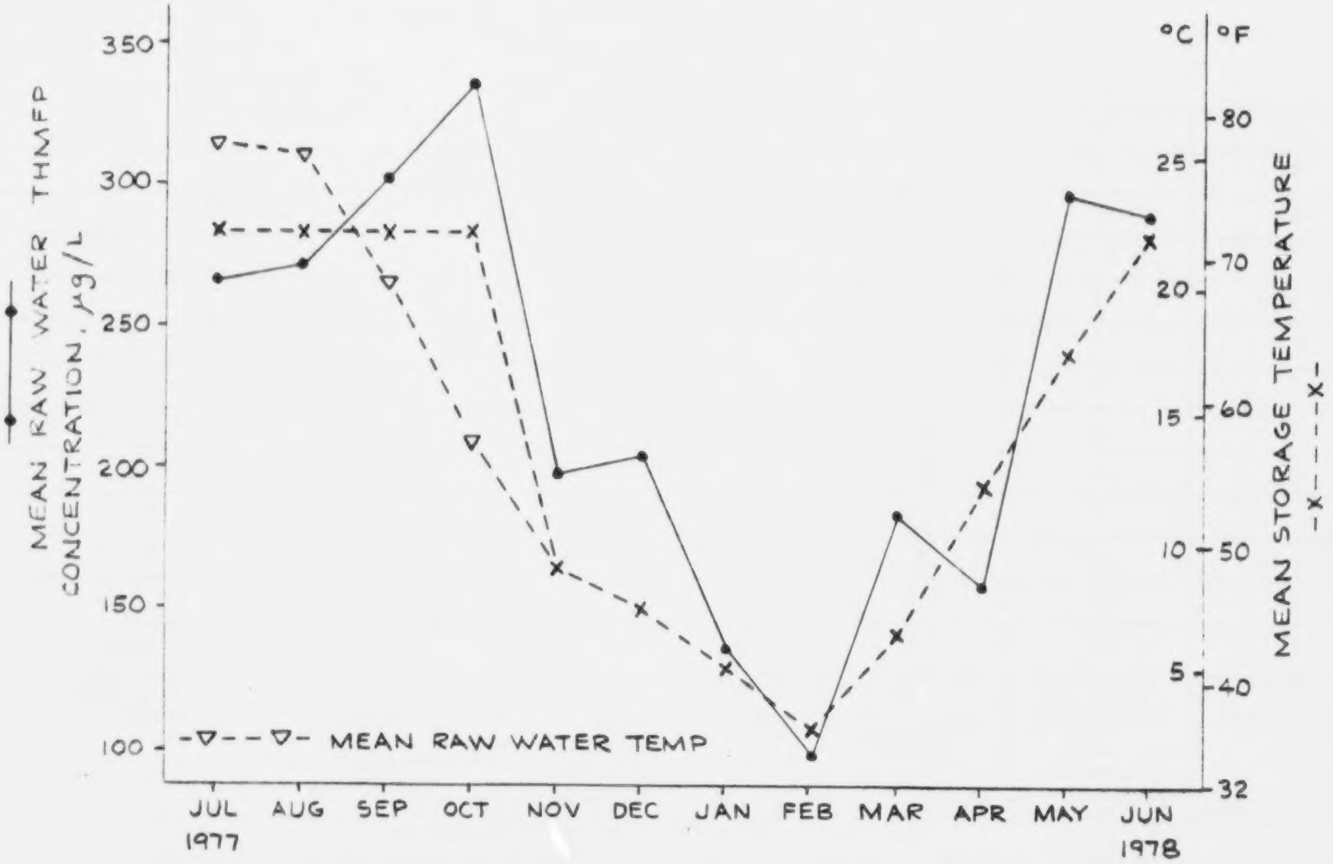


Figure 44. Raw water THMFP variation (mean of project surface waters).

TABLE 58. CARBON TETRACHLORIDE RAW WATER DATA, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	11	0	0								
Wilkinsburg	12	0	0								
Pittsburgh	11	0	1					1	1		
WPW/Hays Mine[b]	7	0	0								
West View[c]	11	0	0								
Beaver Falls	29	0	0							2	0
Wheeling	8	0	0								
Huntington	49	17	6	0.2	0.6	3	3				
Cincinnati	17	4	2	0.1	0.2	3	3			1	0
Louisville	22	3	3	0.1	0.1	2	2				
Evansville	11	1	0	0.1	0.1	1	1				
Total or Mean	188	25	12	0.2	0.6	9	9	1	1	3	0
West View[d]	11	0	0								

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply

TABLE 59. CARBON TETRACHLORIDE FINISHED[a] WATER DATA, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	12	0	2					1	1		
Wilkinsburg	12	0	1					1	1		
Pittsburgh	12	0	1								
WPW/Hays Mine[c]	11	0	1					1	1		
Beaver Falls	27	6	2	0.1	0.2	1	1				
Wheeling	11	1	1	0.1	0.1						
Huntington	22	21	1	0.5	1.8						
Cincinnati	19	3	5	0.2	0.3			1	0		
Louisville	21	4	2	0.4[f]	1.3			1	1		
Evansville	12	4	0	0.2[d]	6.0	1	1				
Total or Mean	159	39	16	0.4	6.0	2	2	5	4		
West View[e]	9	0	0								

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Excluding the maximum concentration of 6 ug/L
e = Ground water supply
f = Excluding the maximum concentration of 1.3 ug/L

TABLE 60. CHLOROBENZENE RAW WATER DATA, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	10	0	0								
Wilkinsburg	12	0	0								
Pittsburgh	11	0	0								
WPW/Hays Mine[b]	7	0	0								
West View[c]	11	0	0								
Beaver Falls	29	0	0								
Wheeling	8	0	0								
Huntington	49	3	2	0.3	1.0	1	1			1	1
Cincinnati	17	0	1								
Louisville[d]	22	1	0	0.1	0.1	1	0				
Evansville	11	0	0								
Total or Mean	187	4	3	0.2	1.0	2	1			1	1
West View[e]	11	4	1	1.7	3.9	1	1			2	0

a = see Figure 1

b = Western Pennsylvania Water Co., Hays Mine Plant

c = Ohio River at West View

d = Not including chlorobenzene spill data.

e = Ground water supply

TABLE 61. CHLOROBENZENE FINISHED[a] WATER DATA, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	11	0	0								
Wilkinsburg	12	0	0								
Pittsburgh	12	0	0								
WPW/Hays Mine[c]	11	0	0								
Beaver Falls	27	0	0								
Wheeling	11	0	0								
Huntington	24	3	1	0.3	0.4	1	1				
Cincinnati	19	1	1	0.2	0.2					1	1
Louisville[d]	21	0	1								
Evansville	12	0	0								
Total or Mean	160	4	3	0.3	0.4	1	1			1	1
West View[e]	9	9	0	1.9	2.9	4	3			1[f]	0

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Not including chlorobenzene spill data.
e = Ground water supply
f = Field replicates: 2.8 ug/L and MS confirmed;
not detected by GC/Hall and MS negative.

TABLE 62. 1,1-DICHLOROETHANE RAW WATER DATA, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Utility[a]	Times Hall searched for	Times Hall found $\geq$0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when $\geq$0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall $\geq$0.1 ug/L	Times MS confirmed when Hall $\geq$0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	9	0	1								
Wilkinsburg	10	0	1					1	1	1	0
Pittsburgh	10	1	3	0.2	0.2	1	0				
WPW/Hays Mine[b]	6	0	0								
West View[c]	8	0	0								
Beaver Falls	25	1	0	0.4	0.4						
Wheeling	7	0	0								
Huntington	34	2	1	0.2	0.3						
Cincinnati	16	1	0							1	0
Louisville	22	0	0								
Evansville	10	0	0								
Total or Mean	157	5	6	0.2	0.4	1	0	1	1	2	0
West View[d]	9	5	2	0.2	0.4	1	1	1	1		

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply

TABLE 63. 1,1-DICHLOROETHANE FINISHED[a] WATER DATA, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	11	0	1					1	0		
Wilkinsburg	10	2	0	0.4	0.6	1	0				
Pittsburgh	10	1	0	0.4	0.4	1	0				
WPW/Hays Mine[c]	11	0	0								
Beaver Falls	22	2	1	0.2	0.4	1	0				
Wheeling	10	0	0								
Huntington	21	1	2	0.2	0.2						
Cincinnati	19	1	1					1	0		
Louisville	18	1	0	0.1	0.1						
Evansville	12	0	0								
Total or Mean	144	8	5	0.3	0.6	3	0	2	0		
West View[d]	9	5	0	0.3	0.7	2	2				

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply

TABLE 64. 1,2-DICHLOROETHANE RAW WATER DATA, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	11	0	1					1	1		
Wilkinsburg	12	1	1	0.2	0.2	1	1				
Pittsburgh	11	1	0	0.6	0.6	1	1				
WPW/Hays Mine[b]	7	0	0								
West View[c]	11	0	0								
Beaver Falls	29	2	5	0.1	0.1	1	1				
Wheeling	8	0	0								
Huntington	49	4	5	0.2	0.4	1	0	1	0		
Cincinnati	17	2	3	0.2	0.3	2	1	1	0		
Louisville	22	5	1	0.3	0.5	3	3				
Evansville	11	1	1	0.1	0.1	1	1				
Total or Mean	188	16	17	0.2	0.6	10	8	3	1		
West View[d]	11	2	1	0.5	0.8			1	0		

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply

TABLE 65. 1,2-DICHLOROETHANE FINISHED[a] WATER DATA, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Utility[b]	Times Hall searched for	Times Hall found $\geq$0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when $\geq$0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall $\geq$0.1 ug/L	Times MS confirmed when Hall $\geq$0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	12	0	0								
Wilkinsburg	12	1	1	0.1	0.1			1	0		
Pittsburgh	12	1	0	< 1	< 1	1	1				
WPW/Hays Mine[c]	11	0	0								
Beaver Falls	26	2	1	0.1	0.2	1	1			1	0
Wheeling	11	0	0								
Huntington	24	0	0							1	0
Cincinnati	19	0	1							2	0
Louisville	21	0	0							1	0
Evansville	12	0	0								
Total or Mean	160	4	3	0.1	0.2	2	2	1	0	5	0
West View[d]	9	1	3	0.5	0.5			1	0		

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply

TABLE 66. 1,2-DICHLOROPROPANE RAW WATER DATA, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	11	0	0								
Wilkinsburg	12	0	1					1	1		
Pittsburgh	11	0	1								
WPW/Hays Mine[b]	7	0	0								
West View[c]	11	0	0								
Beaver Falls	29	0	0								
Wheeling	8	0	1								
Huntington	49	3	7	0.1	0.1	1	1	2	1		
Cincinnati	17	0	1								
Louisville	22	0	2								
Evansville	11	0	5					1	0		
Total or Mean	188	3	18	0.1	0.1	1	1	4	2		
West View[d]	11	0	0								

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply

TABLE 67. 1,2-DICHLOROPROPANE FINISHED[a] WATER DATA, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	12	0	1								
Wilkinsburg	12	1	0	0.1	0.1						
Pittsburgh	12	0	1								
WPW/Hays Mine[c]	11	0	1								
Beaver Falls	27	1	0	0.2	0.2	1	0				
Wheeling	11	0	1								
Huntington	24	2	1	0.1	0.1						
Cincinnati	19	0	0							1	1
Louisville	21	1	0	0.1	0.1						
Evansville	12	1	0	0.1	0.1	1	1				
Total or Mean	161	6	5	0.1	0.2	2	1			1	1
West View[d]	9	0	0								

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply

TABLE 68. TRANS-1,3-DICHLOROPROPENE RAW WATER DATA, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	11	0	0								
Wilkinsburg	12	0	0								
Pittsburgh	11	0	0								
WPW/Hays Mine[b]	7	0	0								
West View[c]	11	0	0								
Beaver Falls	29	0	0								
Wheeling	8	0	0								
Huntington	49	0	0								
Cincinnati	17	0	0								
Louisville	22	0	0								
Evansville	11	0	0								
Total or Mean	188	0	0								
West View[d]	11	0	0								

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply

TABLE 69. TRANS-1,3-DICHLOROPROPENE FINISHED[a] WATER DATA, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L	Times MS confirmation attempted when Hall = not detected	Times MS confirmed when Hall = not detected
Fox Chapel	12	0	0								
Wilkinsburg	12	0	0								
Pittsburgh	12	0	0								
WPW/Hays Mine[c]	11	0	0								
Beaver Falls	27	0	0								
Wheeling	11	0	0								
Huntington	24	0	0								
Cincinnati	19	0	0								
Louisville	21	0	1								
Evansville	12	0	0								
Total or Mean	161	0	1								
West View[d]	9	0	0								

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply

SURVEY FOR BASE-NEUTRAL EXTRACTABLE HALOCARBONS

Discussions of extractable halocarbons are based on GC/Hall and GC/MS analyses of project samples and on accumulated extractable halocarbon quality assurance data (Appendix E). The application of quality assurance data for extraction recovery, analyses of replicate samples, and replicate analyses of sample extracts to the interpretation of project sample data was discussed in Section 5.

1,4-Dichlorobenzene (Raw water data: Table 70. Finished water data: Table 71. Quality assurance data: Table E-1.)

1,4-dichlorobenzene (p-dichlorobenzene) was detected in 55 of 150 raw water extracts and 62 of 154 finished water extracts. GC/MS confirmation attempts for 1,4-dichlorobenzene were positive 85% of the time. Therefore, 1,4-dichlorobenzene was present in project raw and finished waters.

1,4-dichlorobenzene was detected more frequently at and downstream from Huntington than upstream from Huntington. Further support for the presence of the compound in this section of the Ohio River occurred in March 1978 when a dichlorobenzene spill was reported on the Kanawha River. 1,4-dichlorobenzene was GC/Hall detected and GC/MS confirmed in Louisville waters when flow forecasts predicted the spill would pass.

Application of extraction recovery data suggests the following: when detected in project extracts, 1,4-dichlorobenzene was present in project raw and finished waters at concentrations not exceeding 3.1 ug/L (maximum concentration in extract = 1.9 ug/L, extraction recovery approximately 62%, therefore, 1.9/0.62 = 3.1 ug/L in water); following a reported 1,4-dichlorobenzene spill on the Kanawha River, 1,4-dichlorobenzene was present in Louisville waters at approximately 11 ug/L; when not detected in project extracts, 1,4-dichlorobenzene was not present in project raw and finished waters above 0.2 ug/L.

1,4-dichlorobenzene was found in the extracts of raw and finished waters from all project utilities. The precision of project field data for 1,4-dichlorobenzene indicates that raw and finished water concentrations could not be differentiated.

In another ORSANCO project utilizing the same analytical procedure and laboratory, 1,4-dichlorobenzene was present in 80% of the samples from the Kanawha River.[19]

1,3-Dichlorobenzene (Raw water data: Table 72. Finished water data: Table 73. Quality assurance data: Table E-2.)

1,3-dichlorobenzene (m-dichlorobenzene) is a coproduct in the production of 1,4-dichlorobenzene.[20] 1,3-dichlorobenzene was presumptively identified in 12 of 146 raw water extracts and 14 of 151 finished water extracts.

Using the analytical procedure described in Appendix D, 1,3-dichlorobenzene and 1,4-dichlorobenzene elute closely together and were sometimes not well resolved. GC/MS confirmation attempts for 1,3-dichlorobenzene were made on four of the 12 presumptive raw water GC identifications; two of the four confirmed. However, GC/MS confirmation attempts were also made on six raw water extracts when the compound was not GC detected; 1,3-dichlorobenzene was identified in three of the six samples.

1,3-dichlorobenzene was detected more frequently at and downstream from Huntington than upstream from Huntington. Application of extraction recovery data and GC/MS data suggest the following: when presumptively detected in Huntington extracts, 1,3-dichlorobenzene may have been present in Huntington waters at concentrations not exceeding 6.9 ug/L; when presumptively detected in samples from other utilities, 1,3-dichlorobenzene may have been present in those utilities' waters at concentrations not exceeding 1.2 ug/L; when not detected in sample extracts, 1,3-dichlorobenzene was not present in raw and finished waters above 0.2 ug/L; the frequency in which 1,3-dichlorobenzene was identified may be other than that described by Tables 72 and 73.

In another ORSANCO project utilizing the same analytical procedure and laboratory, 1,3-dichlorobenzene was detected in 40% of the samples from the Kanawha River.[19]

1,2-Dichlorobenzene and/or Hexachloroethane (Raw water data: Table 74. Finished water data: Table 75. Quality assurance data: Table E-3.)

1,2-dichlorobenzene (o-dichlorobenzene) is a coproduct in the production of 1,4-dichlorobenzene.[20] 1,2-dichlorobenzene and/or hexachloroethane were detected in 29 of 149 raw water extracts and 39 of 148 finished water extracts. GC/MS confirmation attempts of presumptive identifications of 1,2-dichlorobenzene were positive 67% of the time and GC/MS confirmation attempts for hexachloroethane were positive 20% of the time.

Because of the GC/MS confirmation frequency and because this compound was detected more frequently at and downstream from Huntington (similar to the frequency of detection of 1,3-dichlorobenzene and 1,4-dichlorobenzene), it is believed that 1,2-dichlorobenzene was more likely to have been present than hexachloroethane. Further support for the presence of 1,2-dichlorobenzene in this section of the Ohio River occurred in March 1978 when a dichlorobenzene spill was reported on the Kanawha River. 1,2-dichlorobenzene was GC/Hall detected in Louisville waters when flow forecasts predicted the spill would pass.

Application of extraction recovery data suggests that: when detected in project extracts, 1,2-dichlorobenzene was present in project raw and finished waters at concentrations not exceeding 1.5 ug/L; when not detected in project extracts, 1,2-dichlorobenzene was not present in project raw or finished waters above 0.2 ug/L.

The precision of project field data indicates that raw and finished water concentrations at and downstream from Huntington could not be differentiated.

In another ORSANCO project utilizing the same analytical procedure and laboratory, 1,2-dichlorobenzene and/or hexachloroethane were detected in all samples from the Kanawha River. Both 1,2-dichlorobenzene and hexachloroethane were GC/MS confirmed in that river.[19]

GC/MS confirmation of hexachloroethane in finished waters of the Western Pennsylvania Water Company (Monongahela River) and in the Kanawha River demonstrates the presence of this compound.

1,2,4-Trichlorobenzene and/or Hexachlorobutadiene (Raw water data: Table 76. Finished water data: Table 77. Quality assurance data: Table E-4.)

1,2,4-trichlorobenzene and/or hexachlorobutadiene were detected in 23 of 150 raw water extracts and in 20 of 120 finished water extracts. GC/MS confirmations of 1,2,4-trichlorobenzene were positive 89% of the time. GC/MS confirmations of hexachlorobutadiene proved negative. Based on GC/MS frequency, the compound detected was 1,2,4-trichlorobenzene.

The compound was rarely detected upstream from Cincinnati. The presence of project field data indicates that raw and finished water concentrations at and downstream from Cincinnati could not be differentiated.

Application of extraction recovery data suggests that: when detected in project extracts at Cincinnati, Louisville and Evansville, 1,2,4-trichlorobenzene was present in the raw and finished waters of those utilities at concentrations ranging from 0.2 ug/L to 1.0 ug/L; when not detected in project extracts, 1,2,4-trichlorobenzene was not present in project raw and finished waters above 0.2 ug/L.

Other Halocarbons

Information on the following base-neutral extractable halocarbons is less definitive. The compounds were not detected or were detected in only a few samples at low concentrations. GC/MS confirmation attempts on a limited number of samples for a given compound were always negative. Extraction efficiencies were highly variable.

Following the project data evaluation procedures, limiting concentrations are suggested. These upper limit values apply to the specific analytical procedures used during this study. Data for the following compounds should be used only after reference to the tabulated information.

bis(2-Chloroethyl) Ether and/or bis(2-Chloroisopropyl) Ether--
(Raw water data: Table 78. Finished water data: Table 79. Quality assurance data: Table E-5.)

Detection of these compounds was complicated by interference from dichlorocyclohexane as described in Appendix G. After statistical blank correction of sample chromatograms, the co-eluting compounds were presumptively present in 4 of 267 project extracts; however, the concentrations were too low for GC/MS analyses. Application of extraction recovery data suggests that bis(2-chloroethyl) ether and bis(2-chloroisopropyl) ether were not found in project raw or finished water at concentrations above 0.4 ug/L.

bis(2-Chloroethoxy) Methane--

(Raw water data: Table 80. Finished water data: Table 81. Quality assurance data: Table E-6.)

This compound was infrequently presumptively identified in project extracts (frequency = 27/243). Most of these presumptive data were of insufficient concentration to attempt GC/MS confirmation. The presumptive GC report of highest concentration proved negative by GC/MS.

Extraction recovery data for bis(2-chloroethoxy) methane at low levels were extremely variable. The variability prohibits suggestion of a concentration at which bis(2-chloroethoxy) methane could be reported in project raw and finished waters.

Hexachlorocyclopentadiene--

(Raw water data: Table 82. Finished water data: Table 83. Quality assurance data: Table E-7.)

Hexachlorocyclopentadiene was infrequently presumptively identified in project extracts (frequency = 17/260). When detected by GC/Hall, concentrations were too low for GC/MS confirmation. Extraction recovery data for hexachlorocyclopentadiene at low levels were variable. This variability prohibits suggestion of a concentration at which hexachlorocyclopentadiene could be reported in project raw and finished waters.

2-Chloronaphthalene--

(Raw water data: Table 84. Finished water data: Table 85. Quality assurance data: Table E-8.)

2-chloronaphthalene was presumptively identified in 4 of 150 raw water extracts and in 30 of 120 finished water extracts. GC/MS confirmation proved negative in four of these finished water extracts. GC/MS confirmation attempts of several chlorinated, in-plant waters also proved negative. The compound is not believed to be 2-chloronaphthalene. The compound could not be GC/MS identified. Because of difference in detection frequency and in concentration between raw and finished water extracts, the unidentified compound may be a chlorination product or may be a contaminant in chlorine used for disinfection.

Application of extraction recovery data suggests that when not detected in project extracts, 2-chloronaphthalene was not present in project raw and finished waters above 0.2 ug/L.

4-Chlorophenyl Phenyl Ether--

(Raw water data: Table 86. Finished water data: Table 87. Quality assurance data: Table E-9.)

4-chlorophenyl phenyl ether was rarely presumptively identified in project extracts (4 of 150 raw water extracts and 8 of 155 finished water extracts). Presumptive GC/Hall reports of higher concentrations proved GC/MS negative. Application of extraction recovery data suggests the following: when the compound was not detected in project extracts, 4-chlorophenyl phenyl ether was not present in project raw and finished waters above 0.2 ug/L; when the compound was presumptively identified in project extracts at higher concentrations and GC/MS confirmation was not attempted (frequency = 2/305), the compound may have been present in project waters at approximately 1.0 ug/L.

4-Bromophenyl Phenyl Ether and/or α-BHC--

(Raw water data: Table 88. Finished water data: Table 89. Quality assurance data: Table E-10.)

4-bromophenyl phenyl ether and/or α-BHC were rarely presumptively identified in project extracts (frequency = 4/304). These detections were of insufficient concentration to attempt GC/MS confirmation. Application of extraction recovery data suggests that these compounds were not present in project raw and finished waters above 0.2 ug/L.

γ-BHC (Lindane) and/or δ-BHC--

(Raw Water data: Table 90. Finished water data: Table 91. Quality assurance data: Table E-11).

Lindane and δ-BHC were presumptively identified in 4 of 149 raw water extracts and in 20 of 155 finished water extracts. Concentrations of these presumptively identified compounds were too low for GC/MS confirmation. Application of extraction recovery data suggests the following: when not detected in project extracts, these compounds were not present in project raw or finished waters above 0.2 ug/L; when presumptively identified in project extracts, the compounds may have been present in project finished waters at 0.4 ug/L. The USEPA interim standard for lindane in finished water is 4 ug/L.[15]

Heptachlor and/or β-BHC--

(Raw water data: Table 92. Finished water data: Table 93. Quality assurance data: Table E-12.)

Heptachlor and/or β-BHC were presumptively identified in 42 of 149 raw water extracts and in 43 of 155 finished water extracts. When concentrations were sufficient for GC/MS analysis, the presence of neither compound could be confirmed. Other GC/Hall reports remain presumptive.

The compounds were detected more frequently at Beaver Falls and at and downstream from Huntington than at other utilities. The precision of field data indicates that the concentrations in raw and finished water extracts could not be differentiated.

Application recovery data suggests the following: when not detected in project extracts, heptachlor and β-BHC were not present in project raw or finished waters above 0.2 ug/L; when presumptively identified in project extracts, heptachlor and/or β-BHC may have been present in project raw and finished waters at 0.2-1.5 ug/L.

Aldrin--

(Raw water data: Table 94. Finished water data: Table 95. Quality assurance data: Table E-13.)

Aldrin was presumptively identified in 32 of 149 raw water extracts and in 45 of 155 finished water extracts. GC/MS confirmation proved negative in five of these extracts. GC/MS confirmation attempts of several in-plant waters also proved negative. The compound is not believed to be aldrin. The compound could not be GC/MS identified.

The unidentified compound appeared with greatest frequency at and downstream from Huntington. The precision of field data indicates that the concentrations of the unidentified halocarbon in raw and finished waters could not be differentiated.

Application of extraction recovery data suggests that when not detected in project extracts, aldrin was not present in project raw and finished waters above 0.2 ug/L.

Heptachlor Epoxide--

(Raw water data: Table 96. Finished water data: Table 97. Quality assurance data: Table E-14.)

Heptachlor epoxide appears in the environment as a metabolite of heptachlor.[20] Heptachlor epoxide was rarely detected (frequency = 7/303) in project extracts. Application of extraction recovery data suggests the following: heptachlor epoxide was not present, with one exception, in project raw and finished waters at 0.2 ug/L; on one occasion, the compound may have been present at 0.3 ug/L.

α-Endosulfan--

(Raw water data: Table 98. Finished water data: Table 99. Quality assurance data: Table E-15.)

α-Endosulfan was presumptively identified in 35 of 149 raw water extracts and in 24 of 154 finished water extracts. Presumptive GC/Hall reports at higher concentrations proved GC/MS negative. It is not known whether other GC/Hall reports of lower concentration (extract concentrations of 0.3 ug/L or lower) were α-endosulfan.

Extraction recovery data indicate low recovery of α-endosulfan and suggest the following: α-endosulfan was not present in project raw or finished waters above 3.0 ug/L; when not detected in project extracts, α-endosulfan was not present in project raw and finished waters above 1.0 ug/L.

DDT--

(Raw Water data: Table 100. Finished water data: Table 101. Quality assurance data: Table E-16.)

DDT was presumptively identified in 6 of 303 extracts of project samples. The GC/Hall report of highest concentration proved negative by GC/MS. Application of extraction recovery data suggests that DDT was not present in project raw or finished waters above 0.2 ug/L.

Dieldrin and/or DDE--

(Raw water data: Table 102. Finished water data: Table 103. Quality assurance data: Table E-17.)

Dieldrin appears in the environment as a metabolite of aldrin[20] and DDE as a metabolite of DDT.[20] Dieldrin and/or DDE were rarely presumptively identified (frequency = 6/303) in the extracts of project samples. Application of extraction recovery data suggests that dieldrin and DDE were not present in project raw or finished waters above 0.2 ug/L.

Endrin--

(Raw water data: Table 104. Finished water data: Table 105. Quality assurance data: Table E-18.)

Endrin was presumptively identified in 1 of 303 extracts of project samples. Application of extraction recovery data suggests that endrin was not present in project raw or finished waters above 0.2 ug/L. The USEPA interim standard for endrin in finished water is 0.2 ug/L.[15]

DDD--

(Raw water data: Table 106. Finished water data: Table 107. Quality assurance data: Table E-19.)

DDD appears in the environment as a metabolite of DDT.[20] It was not detected in the extracts of project samples. Application of extraction recovery data suggests that DDD was not present in project raw or finished waters above 0.3 ug/L.

β-Endosulfan--

(Raw water data: Table 106. Finished water data: Table 107. Quality assurance data: Table E-19.)

β-endosulfan was not detected in the extracts of project samples. Application of extraction recovery data suggests that β-endosulfan was not present in project raw and finished waters above 0.3 ug/L.

Methoxychlor--

(Raw water data: Table 108. Finished water data: Table 109. Quality assurance data: Table E-20.)

Methoxychlor was not detected in the extracts of project samples. Application of extraction recovery data suggests that methoxychlor was not present in project raw or finished waters above 0.2 ug/L. The USEPA interim standard for methoxychlor in finished water is 100 ug/L.[15] (Text continues on page 206.)

TABLE 70. 1,4-DICHLOROBENZENE RAW WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	12	0	1						
Wilkinsburg	9	1	1	1.9	1.9	1	1		
Pittsburgh	11	1	2	0.6	0.6				
WPW/Hays Mine[b]	12	2	0	0.3	0.6			1	0
West View[c]	11	0	3						
Beaver Falls	18	0	5						
Wheeling	12	0	4					1	1
Huntington	21	7	4	0.6	1.5	2	2	1	1
Cincinnati	11	4	4	0.5	1.7				
Louisville	11	3	4	0.8	1.1[d]	1	1		
Evansville	11	4	2	0.6	1.5	3	2		
Total or Mean	139	22	30	0.6	1.9	7	6	3	2
West View[e]	11	1	2	1.6	1.6	1	1		

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = 7.0 ug/L during dichlorobenzene spill
e = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 71. 1,4-DICHLOROBENZENE FINISHED[a] WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	11	1	0	1.4	1.4	1	0		
Wilkinsburg	10	0	0						
Pittsburgh	11	0	2						
WPW/Hays Mine[c]	13	1	4	1.2	1.2			1	1
Beaver Falls	20	2	6	0.2	0.2				
Wheeling	12	0	4						
Huntington	23	8	4	0.5	1.3				
Cincinnati	16	5	6	0.4	1.7	1	1		
Louisville	15	4	4	0.6	1.1	1	1	1	1
Evansville	11	3	5	0.2	0.4	3	3		
Total or Mean	142	24	35	0.5	1.7	6	5	2	2
West View[d]	12	1	2	0.6	0.6	1	1		

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 72. 1,3-DICHLOROBENZENE RAW WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[a]	Times Hall searched for	Times Hall found $\geq$0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when $\geq$0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall $\geq$0.1 ug/L	Times MS confirmed when Hall $\geq$0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	12	0	0						
Wilkinsburg	8	0	0					1	0
Pittsburgh	11	0	0						
WPW/Hays Mine[b]	11	0	0					1	0
West View[c]	11	1	1	0.2	0.2				
Beaver Falls	18	1	0	0.2	0.2				
Wheeling	10	0	0					1	0
Huntington	21	3	0	1.4	3.8			3	3
Cincinnati	11	0	1						
Louisville	11	0	1					1	1
Evansville	11	1	2	0.1	0.1	1	1	1	0
Total or Mean	135	5	6	0.9	3.8	1	1	8	4
West View[d]	11	1	0	0.3	0.3			1	0

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 73. 1,3-DICHLOROBENZENE FINISHED[a] WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	11	0	1					1	0
Wilkinsburg	10	0	0						
Pittsburgh	10	0	0						
WPW/Hays Mine[c]	12	0	1						
Beaver Falls	20	1	0	0.6	0.6				
Wheeling	11	0	0						
Huntington	23	4	1	0.9	2.5				
Cincinnati	16	2	0	0.5	0.7				
Louisville	15	1	2	0.2	0.2			1	1
Evansville	11	0	1					2	0
Total or Mean	139	8	6	0.7	2.5			4	1
West View[d]	12	0	0					1	0

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 74. RAW WATER DATA* FOR 1,2-DICHLOROBENZENE AND/OR HEXACHLOROETHANE JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	12	0	0						
Wilkinsburg	9	0	1						
Pittsburgh	11	0	2						
WPW/Hays Mine[b]	12	1	0	0.9	0.9			1 /	0 /
West View[c]	11	0	1						
Beaver Falls	18	0	0						
Wheeling	12	0	0						
Huntington	21	4	5	0.3	0.8	2 / 2	2 / 0	1 /	0 /
Cincinnati	10	1	4	0.2	0.2	1 /	1 /		
Louisville	11	0[d]	4	d	d				
Evansville	11	1	4	0.2	0.2	1 / 1	1 / 0	2 /	1 /
Total or Mean	138	7	21	0.4	0.9	4 / 3	4 / 0	4 /	1 /
West View[e]	11	1	0	0.2	0.2				

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = 0.7 ug/L during dichlorobenzene spill
e = Ground water supply

f / g
f = confirmation of 1,2-dichlorobenzene
g = confirmation of hexachloroethane

*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 75. FINISHED[a] WATER DATA FOR 1,2-DICHLOROBENZENE AND/OR HEXACHLOROETHANE, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	11	0	1						
Wilkinsburg	9	0	2						
Pittsburgh	11	0	2						
WPW/Hays Mine[c]	13	1	2	1.1	1.1	1 / 1	1 / 1		
Beaver Falls	20	1	3	0.1	0.1				
Wheeling	12	0	1						
Huntington	22	3	4	0.2	0.4				
Cincinnati	14	1	7	0.1	0.1			1 /	1 /
Louisville	14	0[d]	3	d	d			1 / 1	0 / 0
Evansville	10	2	5	0.4	0.9	2 / 1	1 / 0		
Total or Mean	136	8	30	0.3	1.1	3 / 2	2 / 1	2 / 1	1 / 0
West View[e]	12	0	1						

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = 0.5 ug/L during dichlorobenzene spill
e = Ground water supply
f / g
f = confirmation of 1,2-dichlorobenzene
g = confirmation of hexachloroethane
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 76. RAW WATER DATA* FOR 1,2,4-TRICHLOROBENZENE AND/OR HEXACHLOROBUTADIENE, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	11	0	0						
Wilkinsburg	9	0	0						
Pittsburgh	11	0	0						
WPW/Hays Mine[b]	12	0	0						
West View[c]	11	0	0						
Beaver Falls	18	0	0						
Wheeling	12	0	0						
Huntington	21	0	0						
Cincinnati	11	3	2	0.1	0.1	1 /	1 /		
Louisville	11	7	2	0.3	0.5	2 / 2	2 / 0		
Evansville	11	4	4	0.3	0.4	2 / 1	2 / 0		
Total or Mean	139	14	8	0.3	0.5	5 / 3	5 / 0		
West View[d]	11	0	1						

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply

e / f — e = confirmation for 1,2,4-trichlorobenzene
f = confirmation for hexachlorobutadiene

*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 77. FINISHED[a] WATER DATA* FOR 1,2,4-TRICHLOROBENZENE AND/OR HEXACHLOROBUTADIENE, JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	11	0	0						
Wilkinsburg	9	0	0						
Pittsburgh	8	0	1						
WPW/Hays Mine[c]	10	0	0						
Beaver Falls	18	0	0						
Wheeling	10	0	1						
Huntington	11	0	0						
Cincinnati	12	1	4	0.3	0.3				
Louisville	11	4	3	0.3	0.3	2 / 2	2 / 0	1 / 1	0 / 0
Evansville	8	3	2	0.3	0.6	1 / 1	1 / 0		
Total or Mean	108	8	11	0.3	0.6	3 / 3	3 / 0	1 / 1	0 / 0
West View[d]	12	0	1						

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply
e / f   e = confirmation for 1,2,4-trichlorobenzene
f = confirmation for hexachlorobutadiene
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 78. BIS(2-CHLOROIOSOPROPYL)ETHER AND/OR BIS(2-CHLOROETHYL)ETHER RAW WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.2 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.2 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.2 ug/L	Times Hall found <0.2 ug/L	Mean Hall concentration when ≥0.2 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.2 ug/L	Times MS confirmed when Hall ≥0.2 ug/L	Times MS confirmation attempted when Hall <0.2 ug/L	Times MS confirmed when Hall <0.2 ug/L
Fox Chapel	12	0	0						
Wilkinsburg	9	0	0						
Pittsburgh	11	0	0						
WPW/Hays Mine[b]	12	0	0						
West View[c]	11	0	0						
Beaver Falls	18	0	0						
Wheeling	12	0	0						
Huntington	21	0	2						
Cincinnati	10	0	0						
Louisville	11	0	1						
Evansville	11	0	0					1	0
Total or Mean	138	0	3					1	0
West View[d]	11	0	0						

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES BUT ARE BLANK CORRECTED. SEE APPENDIX G.

TABLE 79. BIS(2-CHLOROIOSOPROPYL)ETHER AND/OR BIS(2-CHLOROETHYL)ETHER FINISHED[a] WATER DATA,* JULY 1977-JUNE 1978 GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.2 ug/L GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.2 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.2 ug/L	Times Hall found <0.2 ug/L	Mean Hall concentration when ≥0.2 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.2 ug/L	Times MS confirmed when Hall ≥0.2 ug/L	Times MS confirmation attempted when Hall <0.2 ug/L	Times MS confirmed when Hall <0.2 ug/L
Fox Chapel	11	0	0						
Wilkinsburg	9	0	0						
Pittsburgh	8	0	0						
WPW/Hays Mine[c]	10	0	0						
Beaver Falls	17	0	0						
Wheeling	10	0	0						
Huntington	11	0	0						
Cincinnati	11	0	0						
Louisville	11	0	1						
Evansville	8	0	0						
Total or Mean	106	0	1						
West View[d]	12	0	0						

a = Clear well effluent

b = see Figure 1

c = Western Pennsylvania Water Co., Hays Mine Plant

d = Ground water supply

*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES BUT ARE BLANK CORRECTED. SEE APPENDIX C.

TABLE 80. BIS(2-CHLOROETHOXY)METHANE RAW WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1-0.2 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.25 ug/L

Utility[a]	Times Hall searched for	Times Hall found ⩾0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ⩾0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ⩾0.1 ug/L	Times MS confirmed when Hall ⩾0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	12	0	0						
Wilkinsburg	9	0	0						
Pittsburgh	11	0	0						
WPW/Hays Mine[b]	12	0	0						
West View[c]	11	0	0						
Beaver Falls	11	0	1						
Wheeling	11	0	1						
Huntington	20	0	0						
Cincinnati	11	0	0						
Louisville	11	1	6	0.8	0.8	1	0		
Evansville	10	0	3					1	0
Total or Mean	129	1	11	0.8	0.8	1	0	1	0
West View[d]	11	0	0						

a = see Figure 1
b = Western Pennsylvania Water Co, Hays Mine Plant
c = Ohio River at West View
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 81. BIS(2-CHLOROETHOXY)METHANE FINISHED[a] WATER DATA,*
JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1-0.2 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.25 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	11	0	0						
Wilkinsburg	9	0	0						
Pittsburgh	8	0	1						
WPW/Hays Mine[c]	10	0	0						
Beaver Falls	12	1	0	0.1	0.1				
Wheeling	10	1	2	0.1	0.1				
Huntington	9	1	0	0.2	0.2				
Cincinnati	11	0	2						
Louisville	11	0	3						
Evansville	8	1	3	0.2	0.2				
Total or Mean	99	4	11	0.2	0.2				
West View[d]	12	0	0						

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 82. HEXACHLOROCYCLOPENTADIENE RAW WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1-0.2 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.35 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	12	0	0						
Wilkinsburg	9	0	0						
Pittsburgh	11	0	1						
WPW/Hays Mine[b]	12	0	0						
West View[c]	11	0	0						
Beaver Falls	18	0	1						
Wheeling	12	1	0	0.1	0.1				
Huntington	21	0	2						
Cincinnati	11	0	0						
Louisville	11	0	2						
Evansville	11	0	1						
Total or Mean	139	1	7	0.1	0.1				
West View[d]	11	0	0						

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 83. HEXACHLOROCYCLOPENTADIENE FINISHED[a] WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1-0.2 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.35 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	11	0	0						
Wilkinsburg	9	0	0						
Pittsburgh	8	0	1						
WPW/Hays Mine[c]	10	0	0						
Beaver Falls	18	0	2						
Wheeling	10	0	1						
Huntington	11	0	1						
Cincinnati	12	1	0	0.1	0.1				
Louisville	11	1	1	0.2	0.2				
Evansville	8	0	1						
Total or Mean	108	2	7	0.2	0.2				
West View[d]	12	0	0						

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 84. 2-CHLORONAPHTHALENE RAW WATER DATA,* JULY 1977-JUNE 1978 GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	12	0	0						
Wilkinsburg	9	0	0						
Pittsburgh	11	0	0						
WPW/Hays Mine[b]	12	0	0						
West View[c]	11	0	0						
Beaver Falls	18	2	0	0.2	0.2				
Wheeling	12	0	0						
Huntington	21	0	0						
Cincinnati	11	0	0						
Louisville	11	0	1						
Evansville	11	0	1						
Total or Mean	139	2	2	0.2	0.2				
West View[d]	11	0	0						

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 85. 2-CHLORONAPHTHALENE FINISHED[a] WATER DATA,* JULY 1977-JUNE 1978

GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[b]	Times Hall searched for	Times Hall found $\geq$0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when $\geq$0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall $\geq$0.1 ug/L	Times MS confirmed when Hall $\geq$0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	11	0	0						
Wilkinsburg	9	0	0						
Pittsburgh	8	1	1	0.3	0.3				
WPW/Hays Mine[c]	10	0	0						
Beaver Falls	18	12	0	0.5	1.0	1	0		
Wheeling	10	2	1	0.3	0.3	1	0		
Huntington	11	1	1	0.5	0.5				
Cincinnati	12	5	0	0.2	0.3				
Louisville	11	3	0	0.3	0.5	1	0		
Evansville	8	2	1	0.3	0.3	1	0		
Total or Mean	108	26	4	0.4	1.0	4	0		
West View[d]	12	0	0						

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 86. 4-CHLOROPHENYL PHENYL ETHER RAW WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥ 0.1 ug/L	Times Hall found < 0.1 ug/L	Mean Hall concentration when ≥ 0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥ 0.1 ug/L	Times MS confirmed when Hall ≥ 0.1 ug/L	Times MS confirmation attempted when Hall < 0.1 ug/L	Times MS confirmed when Hall < 0.1 ug/L
Fox Chapel	12	0	0						
Wilkinsburg	9	0	0						
Pittsburgh	11	0	1						
WPW/Hays Mine[b]	12	0	0						
West View[c]	11	1	1	0.2	0.2	1	0		
Beaver Falls	18	0	0						
Wheeling	12	0	0						
Huntington	21	0	1						
Cincinnati	11	0	0						
Louisville	11	0	0						
Evansville	11	0	0						
Total or Mean	139	1	3	0.2	0.2	1	0		
West View[d]	11	0	0						

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 87. 4-CHLOROPHENYL PHENYL ETHER FINISHED[a] WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	11	0	0						
Wilkinsburg	10	0	0						
Pittsburgh	11	0	0						
WPW/Hays Mine[c]	13	1	0	0.4	0.4	1	0		
Beaver Falls	20	0	2						
Wheeling	12	0	0						
Huntington	24	0	0						
Cincinnati	16	1	0	0.3	0.3				
Louisville	15	1	1	0.5	0.5				
Evansville	11	1	1	0.4	0.4	1	0	1	0
Total or Mean	143	4	4	0.4	0.5	2	0	1	0
West View[d]	12	0	0						

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 88. 4-BROMOPHENYL PHENYL ETHER AND/OR α-BHC
RAW WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	12	0	0						
Wilkinsburg	9	0	0						
Pittsburgh	11	0	0						
WPW/Hays Mine[b]	11	0	0						
West View[c]	11	0	0						
Beaver Falls	18	0	0						
Wheeling	12	0	0						
Huntington	21	1	1	0.1	0.1				
Cincinnati	11	0	1						
Louisville	11	0	0						
Evansville	11	0	0						
Total or Mean	138	1	2	0.1	0.1				
West View[d]	11	0	0						

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 89. 4-BROMOPHENYL PHENYL ETHER AND/OR α-BHC FINISHED[a] WATER DATA*, JULY 1977-JUNE 1978 GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	11	0	0						
Wilkinsburg	10	0	0						
Pittsburgh	11	0	0						
WPW/Hays Mine[c]	13	0	0						
Beaver Falls	20	0	0						
Wheeling	12	0	0						
Huntington	24	0	0						
Cincinnati	16	0	1						
Louisville	15	0	0						
Evansville	11	0	0						
Total or Mean	143	0	1						
West View[d]	12	0	0						

a = Clear well effluent
b = see Figure 1
c = Western Pennylvania Water Co., Hays Mine Plant
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 90. γ-BHC (LINDANE) AND/OR δ-BHC RAW WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	12	0	0						
Wilkinsburg	9	0	0						
Pittsburgh	11	0	0						
WPW/Hays Mine[b]	11	0	0						
West View[c]	11	0	0						
Beaver Falls	18	0	1						
Wheeling	12	0	0						
Huntington	21	0	2						
Cincinnati	11	0	0						
Louisville	11	0	0						
Evansville	11	0	1						
Total or Mean	138	0	4						
West View[d]	11	0	0						

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 91. γ-BHC (LINDANE) AND/OR δ-BHC FINISHED[a] WATER DATA*
JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	11	0	0						
Wilkinsburg	10	0	0						
Pittsburgh	11	0	0						
WPW/Hays Mine[c]	13	0	0						
Beaver Falls	20	3	5	0.1	0.2			1[d]	0[d]
Wheeling	12	0	1						
Huntington	24	1	4	0.1	0.2				
Cincinnati	16	0	2						
Louisville	15	0	1						
Evansville	11	1	2	0.1	0.1				
Total or Mean	143	5	15	0.1	0.2			1[d]	0[d]
West View[e]	12	0	0						

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Both compounds
e = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 92. HEPTACHLOR AND/OR β-BHC RAW WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	12	0	0						
Wilkinsburg	9	0	0						
Pittsburgh	11	0	1						
WPW/Hays Mine[b]	11	0	0						
West View[c]	11	0	2						
Beaver Falls	18	1	9	0.2	0.2				
Wheeling	12	0	1						
Huntington	21	6	7	0.1	0.9				
Cincinnati	11	2	3	0.2	0.4				
Louisville	11	1	3	0.2	0.2	1[d]	0[d]		
Evansville	11	2	3	0.1	0.2	1[d]	0[d]		
Total or Mean	138	12	29	0.1	0.9	2[d]	0[d]		
West View[e]	11	0	1						

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Both compounds
e = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 93. HEPTACHLOR AND/OR β-BHC FINISHED[a] WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	11	0	0						
Wilkinsburg	10	0	1						
Pittsburgh	11	0	1						
WPW/Hays Mine[c]	13	0	2						
Beaver Falls	20	3	8	0.2	0.4	1[d]	0[d]		
Wheeling	12	0	2						
Huntington	24	5	7	0.1	0.2				
Cincinnati	16	3	4	0.2	0.3				
Louisville	15	0	4					1[d]	0[d]
Evansville	11	2	3	0.1	0.2				
Total or Mean	143	11	32	0.2	0.4	1[d]	0[d]	1[d]	0[d]
West View[e]	12	0	0						

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Both compounds
e = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 94. ALDRIN RAW WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	12	0	1						
Wilkinsburg	9	0	0						
Pittsburgh	11	0	1						
WPW/Hays Mine[b]	11	0	0						
West View[c]	11	0	1						
Beaver Falls	18	0	1						
Wheeling	12	0	1						
Huntington	21	10	2	0.4	2.0				
Cincinnati	11	6	0	0.5	1.3				
Louisville	11	1	3	0.5	0.5	1	0		
Evansville	11	2	1	0.4	0.5	1	0		
Total or Mean	138	19	11	0.4	2.0	2	0		
West View[d]	11	1	1	0.2	0.2				

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 95. ALDRIN FINISHED[a] WATER DATA,* JULY 1977-JUNE 1978 GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	11	0	0						
Wilkinsburg	10	0	0						
Pittsburgh	11	0	0						
WPW/Hays Mine[c]	13	0	1						
Beaver Falls	20	0	1					1	0
Wheeling	12	0	2						
Huntington	24	8	9	0.4	1.2				
Cincinnati	16	7	4	0.4	0.9	2	0		
Louisville	15	4	2	0.4	0.8	1	0		
Evansville	11	2	2	0.3	0.3				
Total or Mean	143	21	21	0.4	1.2	3	0	1	0
West View[d]	12	1	2	0.1	0.1				

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 96. HEPTACHLOR EPOXIDE RAW WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	12	0	0						
Wilkinsburg	9	0	0						
Pittsburgh	11	0	1						
WPW/Hays Mine[b]	11	0	0						
West View[c]	11	0	0						
Beaver Falls	18	0	0						
Wheeling	12	0	0						
Huntington	21	0	0						
Cincinnati	11	0	0						
Louisville	11	1	0	0.2	0.2				
Evansville	11	0	0						
Total or Mean	138	1	1	0.2	0.2				
West View[d]	11	0	0						

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 97. HEPTACHLOR EPOXIDE FINISHED[a] WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[b]	Times Hall searched for	Times Hall found $\geq$0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when $\geq$0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall $\geq$0.1 ug/L	Times MS confirmed when Hall $\geq$0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	11	0	0						
Wilkinsburg	10	0	0						
Pittsburgh	11	0	0						
WPW/Hays Mine[c]	13	0	0						
Beaver Falls	20	0	0						
Wheeling	12	0	1						
Huntington	23	0	0						
Cincinnati	16	0	1						
Louisville	15	0	2						
Evansville	11	0	1						
Total or Mean	142	0	5						
West View[d]	12	0	0						

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 98. α-ENDOSULFAN RAW WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	12	0	2						
Wilkinsburg	9	0	0						
Pittsburgh	11	0	2						
WPW/Hays Mine[b]	11	0	2						
West View[c]	11	1	0	0.2	0.2	1	0		
Beaver Falls	18	2	6	0.6	0.9	1	0		
Wheeling	12	1	2	0.1	0.1				
Huntington	21	1	8	0.2	0.2				
Cincinnati	11	0	3						
Louisville	11	0	2						
Evansville	11	0	2						
Total or Mean	138	5	29	0.4	0.9	2	0		
West View[d]	11	0	1						

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 99. α-ENDOSULFAN FINISHED[a] WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	11	0	0						
Wilkinsburg	10	0	0						
Pittsburgh	11	0	2						
WPW/Hays Mine[c]	13	0	1						
Beaver Falls	20	0	4						
Wheeling	12	0	3						
Huntington	23	1	6	0.2	0.2				
Cincinnati	16	0	2						
Louisville	15	1	3	0.2	0.2	1	0		
Evansville	11	1	0	0.1	0.1				
Total or Mean	142	3	21	0.2	0.2	1	0		
West View[d]	12	0	0						

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 100. DDT RAW WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	12	0	0						
Wilkinsburg	9	0	0						
Pittsburgh	11	0	0						
WPW/Hays Mine[b]	11	0	0						
West View[c]	11	0	0						
Beaver Falls	18	0	0						
Wheeling	12	0	0						
Huntington	21	0	2						
Cincinnati	11	0	0						
Louisville	11	0	0						
Evansville	11	0	0						
Total or Mean	138	0	2						
West View[d]	11	0	0						

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 101. DDT FINISHED[a] WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	11	0	0						
Wilkinsburg	10	0	0						
Pittsburgh	11	0	0						
WPW/Hays Mine[c]	13	0	1						
Beaver Falls	20	0	0						
Wheeling	12	0	0						
Huntington	23	0	0						
Cincinnati	16	1	0	0.2	0.2	1	0		
Louisville	15	0	1						
Evansville	11	0	1						
Total or Mean	142	1	3	0.2	0.2	1	0		
West View[d]	12	0	0						

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 102. DIELDRIN AND/OR DDE RAW WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	12	0	0						
Wilkinsburg	9	0	0						
Pittsburgh	11	0	0						
WPW/Hays Mine[b]	11	0	0						
West View[c]	11	0	0						
Beaver Falls	18	0	0						
Wheeling	12	0	0						
Huntington	21	0	1						
Cincinnati	11	0	0						
Louisville	11	0	0						
Evansville	11	0	0						
Total or Mean	138	0	1						
West View[d]	11	0	0						

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 103. DIELDRIN AND/OR DDE FINISHED[a] WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	11	0	0						
Wilkinsburg	10	0	0						
Pittsburgh	11	0	1						
WPW/Hays Mine[c]	13	0	0						
Beaver Falls	20	0	0						
Wheeling	12	0	0						
Huntington	23	0	1						
Cincinnati	16	0	0						
Louisville	15	0	1						
Evansville	11	0	0						
Total or Mean	142	0	3						
West View[d]	12	0	2						

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 104. ENDRIN RAW WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	12	0	0						
Wilkinsburg	9	0	0						
Pittsburgh	11	0	0						
WPW/Hays Mine[b]	11	0	0						
West View[c]	11	0	0						
Beaver Falls	18	0	0						
Wheeling	12	0	0						
Huntington	21	0	1						
Cincinnati	11	0	0						
Louisville	11	0	0						
Evansville	11	0	0						
Total or Mean	138	0	1						
West View[d]	11	0	0						

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 105. ENDRIN FINISHED[a] WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[b]	Times Hall searched for	Times Hall found $\geq$0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when $\geq$0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall $\geq$0.1 ug/L	Times MS confirmed when Hall $\geq$0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	11	0	0						
Wilkinsburg	10	0	0						
Pittsburgh	11	0	0						
WPW/Hays Mine[c]	13	0	0						
Beaver Falls	20	0	0						
Wheeling	12	0	0						
Huntington	23	0	0						
Cincinnati	16	0	0						
Louisville	15	0	0						
Evansville	11	0	0						
Total or Mean	142	0	0						
West View[d]	12	0	0						

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 106. DDD AND/OR β-ENDOSULFAN RAW WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	12	0	0						
Wilkinsburg	9	0	0						
Pittsburgh	11	0	0						
WPW/Hays Mine[b]	11	0	0						
West View[c]	11	0	0						
Beaver Falls	18	0	0						
Wheeling	12	0	0						
Huntington	21	0	0						
Cincinnati	11	0	0						
Louisville	11	0	0						
Evansville	11	0	0						
Total or Mean	138	0	0						
West View[d]	11	0	0						

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 107. DDD AND/OR β-ENDOSULFAN FINISHED[a] WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	11	0	0						
Wilkinsburg	10	0	0						
Pittsburgh	11	0	0						
WPW/Hays Mine[c]	13	0	0						
Beaver Falls	20	0	0						
Wheeling	12	0	0						
Huntington	23	0	0						
Cincinnati	16	0	0						
Louisville	15	0	0						
Evansville	11	0	0						
Total or Mean	142	0	0						
West View[d]	12	0	0						

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 108. METHOXYCHLOR RAW WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1-0.2 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[a]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	11	0	0						
Wilkinsburg	9	0	0						
Pittsburgh	11	0	0						
WPW/Hays Mine[b]	11	0	0						
West View[c]	11	0	0						
Beaver Falls	18	0	0						
Wheeling	12	0	0						
Huntington	21	0	0						
Cincinnati	11	0	0						
Louisville	11	0	0						
Evansville	11	0	0						
Total or Mean	137	0	0						
West View[d]	11	0	0						

a = see Figure 1
b = Western Pennsylvania Water Co., Hays Mine Plant
c = Ohio River at West View
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

TABLE 109. METHOXYCHLOR FINISHED[a] WATER DATA,* JULY 1977-JUNE 1978
GC/HALL DETECTOR, APPROXIMATE LOWER DETECTION LEVEL = 0.1-0.2 ug/L
GC/MS, APPROXIMATE LOWER DETECTION LEVEL = 0.15 ug/L

Utility[b]	Times Hall searched for	Times Hall found ≥0.1 ug/L	Times Hall found <0.1 ug/L	Mean Hall concentration when ≥0.1 ug/L	Maximum Hall concentration, ug/L	Times MS confirmation attempted when Hall ≥0.1 ug/L	Times MS confirmed when Hall ≥0.1 ug/L	Times MS confirmation attempted when Hall <0.1 ug/L	Times MS confirmed when Hall <0.1 ug/L
Fox Chapel	10	0	0						
Wilkinsburg	10	0	0						
Pittsburgh	11	0	0						
WPW/Hays Mine[c]	13	0	0						
Beaver Falls	20	0	0						
Wheeling	11	0	0						
Huntington	23	0	0						
Cincinnati	15	0	0						
Louisville	14	0	0						
Evansville	11	0	0						
Total or Mean	138	0	0						
West View[d]	12	0	0						

a = Clear well effluent
b = see Figure 1
c = Western Pennsylvania Water Co., Hays Mine Plant
d = Ground water supply
*CONCENTRATIONS NOT CORRECTED FOR EXTRACTION LOSSES.

SURVEY FOR BASE-NEUTRAL EXTRACTABLE NON-HALOGENATED HYDROCARBONS

Analyses were conducted on raw and finished sample extracts by GC/flame ionization detector (GC/FID) and by GC/MS for the non-halogenated extractable hydrocarbons listed in Table 6. These compounds can be generally grouped as phthalate esters and polyaromatic hydrocarbons (PAH). Approximate lower detection levels by GC/FID varied for these compounds from 0.5 ug/L to 10 ug/L; lower detection levels by GC/MS-SIM were 0.1 ug/L.

Implementation of a rigorous quality assurance program, as detailed in Section 5 was necessary after interferences were noted in data produced for these compounds from the first four months of sampling and analysis (July through October 1977). The quality control program included a solvent group concept whereby two solvent blanks were extracted, concentrated and analyzed with each group of four project samples. Interferences were controlled and all data from November 1977 through June 1978 were statistically corrected. Data from the earlier period were discarded.

Phthalates (Quality assurance data: Tables F-1 to F-3.)

GC/FID chromatograms of solvent blanks and sample extracts generally contained responses presumptively identified as phthalate compounds at concentrations at and below the approximate lower detection levels (routine lower quantification levels of 0.5 ug/L to 5.0 ug/L depending on the compound). GC/MS-SIM confirmed the presumptive identifications of these interferences in solvent blanks as phthalates. Concentrations of these contaminants reported in solvent blanks by GC/FID were statistically handled and used in the correction of all sample data. A single compound, bis(2-ethylhexyl) phthalate, that coeluted with 1,2-benzanthracene and/or chrysene, was found in solvent blanks and field extracts well in excess of the approximate lower detection level of 1 ug/L. Statistical corrections at a 95% confidence level of 1.4 ug/L to 4.4 ug/L were applied to sample data for this compound. A few sample extracts contained bis(2-ethylhexyl) phthalate in excess of the statistical correction but these reports were questioned because of the random nature of the contamination. The other phthalate compounds were not detected in sample extracts at concentrations exceeding statistical corrections.

Field extracts did not contain dimethyl phthalate above 5.0 ug/L, diethyl phthalate above 2.0 ug/L, di-n-butyl phthalate above 0.5 ug/L, or butyl benzyl phthalate above 2.0 ug/L. Extreme variability of extraction recovery data prevented their application to field extracts to suggest concentrations above which these phthalates were not likely present in field waters. Because of the random nature of bis(2-ethylhexyl) phthalate contamination and the extreme variability of its extraction recovery data, this phthalate could not be evaluated in field waters.

Polyaromatic Hydrocarbons (Field data: Tables 110 to 114. Quality assurance data: Tables F-1 to F-3.)

PAH compounds were generally not found in samples collected from November 1977 through June 1978 at concentrations exceeding approximate GC/FID lower detection levels (0.5 ug/L to 10 ug/L depending on the compound). However, numerous low level responses were apparent at PAH retention times in GC/FID chromatograms from most utility locations, particularly in the winter months of 1977-78. Initial GC/MS-SIM analyses of a few such selected raw and finished extracts confirmed the presence of some of the PAH compounds at 0.1 ug/L or greater. Further GC/MS-SIM evaluations were then undertaken to qualitatively define PAH compounds at levels ≥0.1 ug/L in extracts of raw and finished water samples from each utility. These evaluations were generally done on a one-time basis for each utility. Extracts from several GAC influent and effluent sequences were also evaluated.

The GC/MS-SIM qualitative results of those evaluations for PAH compounds are presented in Tables 110 through 114. Positive confirmations of the compounds were based on their presence at 0.1 ug/L or greater in sample extracts. Solvent blanks were also analyzed by GC/MS-SIM and did not contain responses for any of the PAH compounds, nor did chromatograms produced by GC/FID analysis of solvent blanks.

Tables 110 and 111 present data for utilities located on the Ohio, Allegheny, Monongahela and Beaver Rivers and for West View's ground water. The importance of these data is that they indicate the confirmed presence of some of the PAH compounds in raw and finished waters of the utilities at concentrations equal to and in excess of 0.1 ug/L. It is important to note that the effect of treatment cannot be evaluated on the basis of a single sample sequence, particularly for a single compound, because the data are qualitative, quality assurance data suggest highly variable extraction recoveries, and identifications are just above the lower detection level for these compounds by GC/MS-SIM.

The data also indicate the absence of eight other PAH compounds in extracts from several utility finished waters. Additional GC/MS-SIM analysis of these seven compounds was not undertaken because positive confirmations were not indicated in initial attempts.

Two sample sequences from the Wheeling Water Department were GC/MS-SIM analyzed, the first sequence collected in the winter season, the second collected in early summer. GC/FID analyses of those sequences had produced visually different chromatograms. Low level responses were apparent in the chromatograms of February raw and finished extracts but were not observed in the chromatograms from samples collected in June. A difference in the number of PAH compounds present in winter and early summer was also supported by the MS data as presented in Table 111.

A significant qualitative difference in raw and finished waters was suggested by GC/MS-SIM analysis of extracts from utilities where treatment included GAC filtration/adsorption. These data are presented in Tables 112 to 114. At the Western Pennsylvania Water Company, seven or eight PAH compounds were present in raw water extracts at or above 0.1 ug/L in two sequences evaluated. With the exception of naphthalene, the compounds were not present at 0.1 ug/L in the associated finished water extracts. The finished water was representative of treatment including GAC filtration/adsorption (Table 112.) PAH compounds present in the extracts of raw waters and of GAC influent waters at or above 0.1 ug/L appeared to be removed by GAC filtration/adsorption at the Huntington Water Corporation and at the Beaver Falls Authority (Tables 113 and 114, respectively). Removal appeared to be more effective with some GACs than with others. In addition to the qualitative nature of the MS data and the variability of extraction recoveries, the GAC type, age and hydraulics should be considered in interpretation of the data.

In research done by others in January 1977,[21] raw and finished water samples from the Western Pennsylvania Water Company Hays Mine Plant (WPW) and the Huntington Water Corporation were analyzed for six PAH compounds. At WPW, a total concentration of 0.6 ug/L for the compounds evaluated was reported for the raw water, including the reported presence of 0.4 ug/L of fluoranthene. The total concentration of PAH compounds reported in the finished water was 0.003 ug/L, a concentration well below the 0.1 ug/L for GC/MS lower detection levels of PAHs reported in Table 112. At the Huntington Water Corporation, however, the total concentration reported for the raw water was 0.06 ug/L; that reported for the finished water was 0.007 ug/L. Both concentrations were below the detection level at which PAH compounds were confirmed by project data in 1978.

All qualitative data presented for project utilities are based on the presence at $\geqslant$0.1 ug/L of some or all of a group of seven to eight PAH compounds in the extract of a field sample. An extract containing six PAH compounds at a concentration of $\geqslant$0.1 ug/L (Table 111) would contain a total concentration for those compounds of $\geqslant$0.6 ug/L. While the relationship of the concentration in the extract to that present in the field sample is not defined because of variable extraction recoveries (Table F-1), it is very likely that concentrations were higher in the field samples. The World Health Organization has recommended[22] that the concentration of six representative PAH compounds be limited to 0.2 ug/L in treated surface waters. One of the six representative compounds was fluoranthene, a PAH confirmed in project extracts.

Because these GC/MS-SIM data are generally based on a single sequence at each project utility, they should be considered as initial findings. It is apparent, however, that some PAH compounds were present during the winter months of 1977-78 in raw and finished waters. Some GAC filter/adsorbers appeared to be effective in their removal. Research into the presence and significance of polynuclear aromatic hydrocarbons in drinking water is required. (Text continues on page 214.)

TABLE 110. MASS SPECTROMETRY-SELECTED ION MONITORING (SIM) CONFIRMATION[a] OF BASE-NEUTRAL EXTRACTED NON-HALOGENATED PRIORITY POLLUTANTS

Utility	Fox Chapel		Wilkinsburg		Pittsburgh		Beaver Falls		West View[b]	
Date	1-31-78		2-15-78		1-23-78		3-28-78		6-1-78	
Compound / Water	R	F	R	F	R	F	R	F	R	F
Naphthalene	+	+	-	-	TR	+	-	+	-	-
Acenaphthylene	-	-	-	-	TR	-	-	+	-	+
Acenaphthene	-	-	-	-	-	-	+	+	+	+
Fluorene	-	-	-	-	+	+	+	+	-	-
Phenanthrene and/or Anthracene	-	-	-	-	+	+	+	+	+	+
Fluoranthene	-	-	-	-	+	+	+	+	+	-
Pyrene	-	-	-	-	+	+	+	+	+	+
1,2-Benzanthracene and/or Chrysene						-		-		
3,4-Benzofluoranthene and/or 11,12-Benzofluoranthene						-		-		
Benzo(a)pyrene						-		-		
Indeno(1,2:C,D)pyrene						-		-		
1,2:5,6-Dibenzanthracene and/or 1,12-Benzoperylene						-		-		

[a] MS-SIM detection level approximately 0.1 ug/L
+ = present ≥0.1 ug/L in extracted concentrate of sample
- = not detected ≥0.1 ug/L in extracted concentrate of sample
TR = trace

[b] Ground water supply

R = raw
F = finished

TABLE 111. MASS SPECTROMETRY-SELECTED ION MONITORING (SIM) CONFIRMATION[a] OF BASE NEUTRAL-EXTRACTED NON-HALOGENATED PRIORITY POLLUTANTS

Utility	Wheeling				Cincinnati		Louisville		Evansville	
Date	2-21-78		6-21-78		2-13-78		12-13-77		2-15-78	
Compound / Water	R	F	R	F	R	F	R	F	R	F
Naphthalene	-	+	+	-	+	+	+	+	-	+
Acenaphthylene	+	+	-	-	+	-	-	-	-	-
Acenaphthene	+	+	-	-	+	+	-	-	-	-
Fluorene	+	+	-	-	+	+	-	-	-	+
Phenanthrene and/or Anthracene	+	+	-	+	+	+	+	-	+	+
Fluoranthene	+	+	+	+	+	+	+	-	+	+
Pyrene	+	+	+	+	+	+	+	-	+	+
1,2-Benzanthracene and/or Chrysene		-				-				-
3,4-Benzofluoranthene and/or 11,12-Benzofluoranthene		-				-				-
Benzo(a)pyrene		-				-				-
Indeno(1,2:C,D)pyrene		-				-				-
1,2:5,6-Dibenzanthracene and/or 1,12-Benzoperylene		-				-				-

[a] MS-SIM detection level approximately 0.1 ug/L
+ = present ≥0.1 ug/L in extracted concentrate of sample
- = not detected ≥0.1 ug/L in extracted concentrate of sample
TR = trace
[b] Ground water supply

R = raw
F = finished

TABLE 112. MASS SPECTROMETRY-SELECTED ION MONITORING (SIM) CONFIRMATION[a] OF BASE-NEUTRAL EXTRACTABLE NON-HALOGENATED PRIORITY POLLUTANTS, WESTERN PENNSYLVANIA WATER COMPANY

Date	February 14, 1978		April 12, 1978	
Compound / Water	Raw	Finished[b,c]	Raw	Finished[b,d]
Naphthalene	+	+	+	+
Acenaphthylene	+	-	+	-
Acenaphthene	+	-	+	-
Fluorene	+	-	+	-
Phenanthrene and/or Anthracene	+	-	+	-
Fluoranthene	+	-	+	-
Pyrene	+	-	+	-

[a] MS-SIM detection level approximately 0.1 ug/L

+ = present ≥0.1 ug/L in sample extract

- = not detected ≥0.1 ug/L in sample extract

[b] Treatment includes filtration/adsorption

GAC = Filtrasorb 400

Approximate loading rate = 2.3 m/hr (1.0 gpm/ft^2)

Approximate EBCT = 18 minutes

Depth = 76 cm (30 inch) GAC

[c] GAC age = 26 months

[d] GAC age = 28 months

TABLE 113. MASS SPECTROMETRY-SELECTED ION MONITORING (SIM) CONFIRMATION[a] OF BASE-NEUTRAL EXTRACTABLE NON-HALOGENATED PRIORITY POLLUTANTS, HUNTINGTON WATER CORPORATION

Date	February 14, 1978						March 14, 1978			
		GAC[b]						GAC[b]		
Compound / Water	R	Inf	Eff[c]	Eff[d]	Eff[e]	F	R	Inf	Eff[f]	F
Naphthalene	+	+	-	+	+	+	+	+	-	-
Acenaphthylene	+	+	-	-	-	-	-	-	-	-
Acenaphthene	+	-	-	-	-	-	-	-	-	-
Fluorene	+	+	-	-	-	-	-	-	-	-
Phenanthrene and/or Anthracene	+	+	-	-	-	+	+	+	-	+
Fluoranthene	+	+	-	-	-	+	+	+	-	+
Pyrene	+	+	-	-	-	+	+	+	-	+

[a] MS-SIM detection level approximately 0.1 ug/L
+ = present ⩾0.1 ug/L in sample extract
- = not detected ⩾0.1 ug/L in sample extract

[b] GAC = WVW 14x40
Depth = 76 cm (30 inch) GAC
Approximate loading rate = 6.1 m/hr (2.6 gpm/ft^2)
Approximate EBCT = 7.2 minutes

[c] GAC age = 8 months

[d] GAC age = 16 months

[e] GAC age = 34 months

[f] GAC age = 9 months

GAC = granular activated carbon
R = raw
Inf = influent
Eff = effluent
F = finished

TABLE 114. MASS SPECTROMETRY-SELECTED ION MONITORING (SIM) CONFIRMATION[a] OF BASE-NEUTRAL EXTRACTABLE NON-HALOGENATED PRIORITY POLLUTANTS, BEAVER FALLS AUTHORITY

Date	January 2, 1978				January 18, 1978			
	GAC[b,c]				GAC[b,d]			
Compound / Water	Inf	F400 Eff	FC Eff	ICI Eff	Inf	F400 Eff	FC Eff	ICI Eff
Naphthalene	+	-	+	+	+	+	+	+
Acenaphthylene	+	-	-	+	-	-	-	+
Acenaphthene	-	-	-	-	-	-	-	-
Fluorene	+	-	-	+	+	-	+	+
Phenanthrene and/or Anthracene	+	-	-	+	+	-	-	+
Fluoranthene	+	-	+	+	+	-	-	-
Pyrene	+	-	-	+	-	-	-	-

[a] MS-SIM detection level approximately 0.1 ug/L
+ = present ≥0.1 ug/L in sample extract
- = not detected ≥0.1 ug/L in sample extract

[b] Depth = 61 cm (24 inch) GAC
Approximate loading rate = 3.1-3.5 m/hr (1.3-1.5 gpm/ft^2)
Approximate EBCT = 10.1-11.4 minutes

[c] GAC age = 3½ months

[d] GAC age = 4 months

GAC = granular activated carbon
Inf = influent
Eff = effluent
F400 = Filtrasorb 400
FC = Filtrasorb C
ICI = Hydrodarco 8x16

ORGANIC COMPOUNDS NOT DESIGNATED AS PRIORITY POLLUTANTS

GC/MS identification of recurring unknowns was attempted when the GC/Hall, GC/FI or GC/alkali detector responses indicated sufficient concentration (1 ug/L) for GC/MS analysis. Some recurring unknowns were identified, others were not.

trans-1,2-Dichloroethylene

This compound was confirmed by GC/MS-SIM at concentrations at or above 0.1 ug/L once in finished water at Wheeling, once in raw, Filtrasorb 400 GAC effluent and finished water at Beaver Falls, and once in finished ground water at West View. GC/Hall analyses of these utilities' waters presumptively indicate the occasional presence of this compound.

Squalene

Squalene was identified by GC/MS in an untreated surface water at Wheeling at a concentration exceeding 1 ug/L. The compound had a retention time of 1.65 relative to hexachlorobenzene when using the procedure detailed in Appendix D.

1,2,3,4-Tetrahydronaphthalene (Tetralin)

Tetralin was identified by GC/MS in an untreated surface water at Louisville at a concentration exceeding 1 ug/L. The compound had a retention time of 0.41 relative to hexachlorobenzene when using the procedure detailed in Appendix D.

6-Tertiary butyl meta cresol and 2,6-Tertiary dibutyl meta cresol

These cresols were identified once by GC/MS in untreated surface water at Wilkinsburg and in untreated ground water at West View. The 6-tertiary butyl meta cresol was identified by GC/MS in an untreated surface water at Fox Chapel. Concentrations were at or above 1 ug/L in each sample. Retention times relative to hexachlorobenzene were 0.67 for the butyl cresol and 0.93 for the dibutyl cresol when using the procedure detailed in Appendix D.

Unidentified Compounds Resulting from Chlorination--

At several utilities, compounds were detected in chlorinated waters that were rarely detected in raw waters. These compounds may be products of chlorination or may be contaminants in chlorine used for disinfection. When detected, concentrations in in-plant waters were typically lower than concentrations in finished waters possibly because chlorine contact time in in-plant waters was less than in finished waters or because finished waters had been chlorinated twice. Concentrations of these compounds were insufficient for GC/MS identification.

Raw and finished water data for three unidentified base-neutral extractable halocarbons are presented in Tables 115 through 117. These data demonstrate the presence of these unidentified halocarbons in finished waters at greater frequency and at higher concentrations than in raw water. Data presented in Tables 84 and 85 demonstrate the same for a compound which was presumptively identified as 2-chloronaphthalene but which could not be GC/MS confirmed as 2-chloronaphthalene and could not be identified. It may have been a halocarbon resulting from the application of chlorine.

These unidentified halocarbons were detected less frequently and at lower concentration at utilities (West View, Fox Chapel, Wilkinsburg, Western Pennsylvania Water Company) that demonstrated lower formation of trihalomethanes than other utilities (see Table 46), suggesting that these halocarbons, like the trihalomethanes, may be chlorination products.

At the Western Pennsylvania Water Company in July, a purgeable halocarbon was detected in chlorinated waters that was not detected in raw water. The compound could not be GC/MS identified. These data are presented in Table 115. This compound was not detected at other times at the utility. A purgeable halocarbon with a similar relative retention time was frequently found in Beaver Falls' finished water but rarely in its raw water. It could not be GC/MS identified.

TABLE 115. UNIDENTIFIED PURGEABLE HALOCARBON[a] DATA
WESTERN PENNSYLVANIA WATER COMPANY, JULY 5-14, 1978
GC/HALL DETECTOR, (MEAN VALUES)

Water	Concentration,[b] ug/L
raw	ND
chlorinated raw	0.3
clarified	0.6
settled	0.7
GAC filtered	0.6
finished	0.3

[a] Using procedure described in Appendix B, compound has retention time of approximately 0.70 relative to 1,4-dichlorobutane.

[b] Quantification based on 1,4-dichlorobutane.

TABLE 116. UNIDENTIFIED BASE-NEUTRAL EXTRACTABLE HALOCARBON[a] DATA[b,c]
JULY 1977-JUNE 1978, GC/HALL DETECTOR

	Raw Water					Finished Water				
Utility	Times GC Searched For	Times GC Found ≥0.1 ug/L	Times GC Found <0.1 ug/L	Mean Concentration When Found ≥0.1 ug/L	Maximum GC Concentration	Times GC Searched For	Times GC Found ≥0.1 ug/L	Times GC Found <0.1 ug/L	Mean Concentration When Found ≥0.1 ug/L	Maximum GC Concentration
Fox Chapel	12	0	0			11	0	0		
Wilkinsburg	9	0	0			10	0	1		
Pittsburgh	11	0	0			11	0	5		
WPW/Hays Mine[d]	12	0	0			13	0	1		
West View[e]	11	0	0			--	--	--		
Beaver Falls	18	0	1			20	2	11	0.2	0.2
Wheeling	12	0	1			12	0	5		
Huntington	21	0	0			24	1	3	0.1	0.1
Cincinnati	11	0	0			16	0	7		
Louisville	11	0	0			15	1	5	0.1	0.1
Evansville	11	0	0			11	4	2	0.2	0.3
Total or Mean	139	0	2			143	8	40	0.2	0.3
West View[f]	11	0	0			12	0	0		

a = Using procedure described in Appendix D, compound has retention time of approximately 0.75 relative to hexachlorobenzene.
b = Quantification based on hexachlorobenzene.
c = NOT CORRECTED FOR EXTRACTION LOSSES.
d = Western Pennsylvania Water Co., Hays Mine Plant.
e = Ohio River at West View.
f = Ground water supply.

TABLE 117. UNIDENTIFIED BASE-NEUTRAL EXTRACTABLE HALOCARBON[a] DATA [b,c] JULY 1977-JUNE 1978, GC/HALL DETECTOR

Utility	Raw Water					Finished Water				
	Times GC Searched For	Times GC Found ≥0.1 ug/L	Times GC Found <0.1 ug/L	Mean Concentration When Found ≥0.1 ug/L	Maximum GC Concentration	Times GC Searched For	Times GC Found ≥0.1 ug/L	Times GC Found <0.1 ug/L	Mean Concentration When Found ≥0.1 ug/L	Maximum GC Concentration
Fox Chapel	12	0	0			11	0	1		
Wilkinsburg	9	0	0			10	0	1		
Pittsburgh	11	0	0			11	2	0	0.1	0.2
WPW/Hays Mine[d]	12	0	1			13	0	3		
West View[e]	11	0	0			--	--	--		
Beaver Falls	18	0	1			20	2	5	0.2	0.2
Wheeling	12	0	3			12	0	7		
Huntington	21	0	0			24	4	8	0.2	0.3
Cincinnati	11	0	0			16	3	3	0.2	0.3
Louisville	11	0	0			15	4	6	0.3	0.4
Evansville	11	0	1			11	2	3	0.4	0.5
Total or Mean	139	0	6			143	17	37	0.2	0.5
West View[f]	11	0	0			12	0	0		

a = Using procedure described in Appendix D, compound has retention time of approximately 0.77 relative to hexachlorobenzene.

b = Quantification based on hexachlorobenzene.

c = NOT CORRECTED FOR EXTRACTION LOSSES.

d = Western Pennsylvania Water Co., Hays Mine Plant.

e = Ohio River at West View.

f = Ground water supply.

TABLE 118. UNIDENTIFIED BASE-NEUTRAL EXTRACTABLE HALOCARBON[a] DATA[b,c] JULY 1977-JUNE 1978, GC/HALL DETECTOR

Utility	Raw Water					Finished Water				
	Times GC Searched For	Times GC Found ≥0.1 ug/L	Times GC Found <0.1 ug/L	Mean Concentration When Found ≥0.1 ug/L	Maximum GC Concentration	Times GC Searched For	Times GC Found ≥0.1 ug/L	Times GC Found <0.1 ug/L	Mean Concentration When Found ≥0.1 ug/L	Maximum GC Concentration
Fox Chapel	12	0	0			11	0	0		
Wilkinsburg	9	0	0			10	0	0		
Pittsburgh	11	0	0			11	0	0		
WPW/Hays Mine[d]	12	1	0	0.1	0.1	13	0	1		
West View[e]	11	0	0			--	--	--		
Beaver Falls	18	0	0			20	1	1	0.9	0.9
Wheeling	12	0	1			12	2	0	0.2	0.2
Huntington	21	0	1			24	5	2	0.2	0.3
Cincinnati	11	0	0			16	5	3	0.4	0.5
Louisville	11	0	0			15	4	0	0.3	0.5
Evansville	11	0	0			11	4	1	0.6	0.9
Total or Mean	139	1	2	0.1	0.1	143	21	8	0.4	0.9
West View[f]	11	0	0			12	0	0		

a = Using procedure described in Appendix D, compound has retention time of approximately 0.81 relative to hexachlorobenzene.

b = Quantification based on hexachlorobenzene.

c = NOT CORRECTED FOR EXTRACTION LOSSES.

d = Western Pennsylvania Water Co., Hays Mine Plant.

e = Ohio River at West View.

f = Ground water supply.

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APPENDIX A

GENERAL ORGANIC LABORATORY PROCEDURES

GLASSWARE CLEANING AND HANDLING

Sample Bottles

Three sizes of sample containers were used for project organic sampling. Forty mL Flint glass vials with Teflon-lined screw caps were used for collection of purgeable samples. Two hundred and seventy mL standard laboratory Pyrex glass bottles with Teflon-lined screw caps were used for collection and storage of terminal level purgeable samples. Gallon Pyrex glass bottles with Teflon-lined screw caps were used for collection of extractable samples. In the laboratory at the time of analysis, 12 mL Flint glass vials with Teflon-lined screw caps were used to contain a transferred portion of the 40 mL samples.

Forty mL and 12 mL vials were cleaned with detergent and tap water, rinsed with deionized tap water and oven treated at 250-300°C for two hours. After cooling, sodium thiosulfate powder was added to each 40 mL vial to eliminate residual chlorine at the sample site; these vials were tightly capped and stored or packed for shipment to the sample site.

Two hundred and seventy mL bottles were washed in the same manner as the vials. After rinsing, they were kiln heated for two hours at 250°C. Sodium thiosulfate was not added. Thirty mL of concentrated buffer solution was added in order to maintain the utility's finished water pH during storage. The bottles were tightly capped and stored or packed for shipment.

Gallon bottles were washed with detergent and tap water, rinsed with deionized tap water, rinsed with acetone, and given a final rinse with methylene chloride. The gallon bottles were drained and air dried. After approximately one gram of sodium thiosulfate was added, each bottle was tightly capped and stored or packed for shipment.

The Teflon caps were washed with detergent and tap water, rinsed with deionized tap water and air dried.

Laboratory Glassware

All laboratory glassware used in handling project samples was cleaned by washing with detergent and tap water, rinsing with deionized tap water and air drying. This included such extraction glassware as Kuderna-Danish (K-D) evaporation apparatus, funnels, separatory funnels, graduated cylinders, one-liter amber bottles for storage of extracts prior to concentration, and 2 mL ampules for storage of concentrated extracts. Additionally, separatory funnels were chromic acid washed. K-D apparatus was methylene chloride rinsed, washed with detergent, rinsed with deionized tap water and oven dried at 110°C for 30 minutes. To minimize interference from phthalate esters, these procedures were revised for all extraction glassware to include distilled water rinsing, acetone rinsing and kiln firing at 400°C for 30 minutes.

Materials

Detergent used in washing was RSB-35, a surface active agent from the Pierce Chemical Company. Austin, Texas, tap water was used for washing and deionized Austin tap water for rinsing. Solvents for rinsing were Burdick and Jackson distilled-in-glass quality. Anhydrous sodium thiosulfate (Baker Analyzed Reagent) was used in the designated sample containers for residual chlorine reduction.

Buffers used during storage of terminal level purgeable samples were prepared with halide-free (Baker Analyzed Reagent) chemicals and low organic distilled water.

PREPARATION OF LOW ORGANIC WATER

Water used for purgeable blank analyses, preparation of purgeable standards and rinsing of purging apparatus was prepared from deionized tap water. The water was sparged for 30 minutes with zero grade nitrogen at 100-200 cc/minute and then sparged continuously at a reduced rate until used.

Distilled water used for recovery tests for extractable compounds, for rinsing laboratory glassware and for preparation of buffers was prepared in the following manner. Deionized tap water was distilled over a solution of potassium permanganate and sodium hydroxide. During the distillation, a stream of zero grade nitrogen was passed through the aqueous solution at 50-100 cc/minute. The distilled water was used from the receiver on the still or stored in a 20 liter glass bottle with a Teflon-lined screw cap. (The storage bottle was cleaned with chromic acid, washed with detergent and tap water and rinsed sequentially with deionized tap water, acetone, methylene chloride and low organic distilled water.)

OTHER CONTROLS

General

Only high purity laboratory products were employed in the analytical procedures. Solvents used were Burdick and Jackson distilled-in-glass quality. Standard solutions of the Priority Pollutants of interest were prepared from 99+% pure reference standard compounds. Gases were zero grade purity and were cleaned using a 5A molecular sieve placed after the regulators. Further cleaning of purge and carrier gases for purgeable analyses was achieved with the use of a 6.4 mm (¼-inch) OD by 28 cm stainless steel trap packed with Tenax and Chromosorb 102 placed in the gas line after the molecular sieve.

These traps were cleaned periodically by disconnecting them and heating at 200°C. System transfer lines were stainless steel. For purgeable analyses, short transfer lines from the desorption unit to the GC columns were used to eliminate "memory" problems in the system. Teflon parts were eliminated from the system where temperatures were in excess of 150°C.

Interference from Laboratory Air

Possible sources of laboratory air contamination include laboratory solvents, cleaning compounds, refrigerants and building materials. Contamination from the air cannot easily be eliminated. Therefore, the laboratory insured that system parts which came into contact with the project samples, carrier gasses or purge gasses were not exposed to laboratory air. A Luer-Lok Valve was used on the purging vessel to introduce the sample and then close out laboratory air. Project samples were rapidly introduced to the purging vessel after uncapping in order to minimize exposure to laboratory air.

SAMPLE STORAGE

Upon receipt at the laboratory, samples were numbered and recorded. Both purgeable and extractable samples were refrigerated at 2-10°C.

At the time of analysis, a portion of the 40 mL purgeable sample was transferred headspace free to a 12 mL vial sealed with a Teflon-lined screw cap. The 12 mL vials were stored at 2-10°C for reanalysis, if desired.

When possible, purgeable samples were analyzed within two weeks of receipt at the laboratory. During a long period, however, when instrumentation was revised, these samples were held refrigerated for four to six months before analysis.

Extractable samples were extracted as soon as laboratory time permitted. The extract was either concentrated the same day or was stored in one liter amber glass bottles sealed with Teflon-lined screw caps at 2-10°C overnight for concentration the next day. All concentrates were stored at 2-10°C in 2 mL ampules sealed with Teflon-lined septa.

Extractable samples were typically extracted and concentrated within three days of receipt at the laboratory. During one period, however, when procedures were revised to minimize interferences, these samples were held refrigerated for three to six weeks before extraction and concentration.

APPENDIX B

EQUIPMENT AND ANALYTICAL PROCEDURES FOR PURGEABLE HALOCARBON PRIORITY POLLUTANTS

STANDARDS

Primary standard solutions at one part per thousand were prepared as a group from 99+% pure halocarbon standard compounds in Burdick and Jackson distilled-in-glass quality methanol in a volumetric flask as follows. The flask was partially filled with methanol. Because the halocarbons are volatile, these liquids were weighed in a tared microsyringe to prevent evaporation during measurement. A 10 uL syringe was rinsed twice with a standard compound and then brought to a predetermined volume of the standard by weight. This volume was introduced into the methanol along with several methanol rinsings of the syringe. The process was repeated for each purgeable standard compound and the final solution was brought to volume in the flask with methanol. This stock solution was transferred to vials sealed with Teflon-lined septa for freezer storage for up to six months.

A secondary standard in methanol at twenty parts per million was prepared from the primary standard and similarly sealed in vials for freezer storage for up to six months. The secondary standard solution was used for daily preparation of calibration standards at ten parts per billion (ug/L) by dilution in low organic water. A single vial of secondary standard was used daily for up to three weeks, with the Teflon septum being replaced with each use.

Primary and secondary standard solutions of internal standard 1,4-dichlorobutane were prepared in the same manner.

EQUIPMENT

A purge, trap and desorption device was interfaced to a Tracor model 560 gas chromatograph equipped with a digital temperature programmer. The GC was interfaced to a Tracor model 700 Hall electrolytic conductivity detector. Output from the system was integrated and recorded by a Hewlett Packard model 3380A integrator.

Initially, purge, trap and desorption was performed by a Tekmar model LSC-1. This unit was replaced by purge, trap and desorption units made by Radian Corporation.

PROCEDURE

Forty mL sample vials were opened and a portion of the sample was rapidly transferred to a 5 mL syringe for introduction to a purging vessel. The remaining portion was transferred headspace free into a 12 mL storage vial and sealed with a Teflon-lined screw cap.

The internal standard, 1,4-dichlorobutane, was introduced by syringe to the purging vessel. The sample was purged with nitrogen at 40 cc/minute for twelve minutes. The volatile compounds were trapped on a resin bed of 10 cm of Tenax GC followed by 5 cm of Chromosorb 102 in a glass-lined 3.5 mm OD stainless steel trap.

When the purging was complete, the trapped compounds were desorbed for three minutes with the Radian Corporation made unit. A desorption temperature of 180°C was reached in approximately 40 seconds. Desorption was onto the head of a GC column at room temperature.

The GC was equipped with a 3.7 m by 0.35 cm glass column packed with 0.2% Carbowax 1500 on 60/80 mesh Carbopack C. The 0.3 m pre-column contained 3% Carbowax 1500 on 60/80 mesh Chromosorb W-HP. The GC column oven was rapidly heated to 60°C, held at 60°C for four minutes, then programmed to 170°C at 8°C/minute. When only the trihalomethane compounds were being analyzed (terminal level samples), the column oven was rapidly heated to 60°C after desorption, the initial four minute hold was deleted, and the temperature was programmed from 60° to 170°C at 10°C/minute. The carrier gas was nitrogen at 40 cc/minute.

The electrolytic conductivity detector was operated in the halogen specific mode. The HP 3380A integrator was operated in the internal standard mode. Quantification by internal standard was based on the formula:

$$Cy = (Ay \times Ry \times Ci)/(Ai \times Ri)$$

where

Cy = concentration, ug/L, of compound y in sample
Ay = chromatographed area of compound y in sample
Ry = response factor for compound y in calibration
Ai = chromatographed area for internal standard in sample
Ri = response factor for internal standard in calibration
Ci = concentration, ug/L, of internal standard in sample

$$\text{response factor} = \frac{\text{concentration, ug/L, in calibration}}{\text{chromatographed area in calibration}}$$

Between sample analyses, the sample syringe and the purging apparatus were rinsed three times with low organic blank water. At the end of each day's operation or after a sample analysis with high organic concentrations, the syringe and purging apparatus were rinsed with acetone and blank water. Between sample analyses, the trap was baked out at 180°C for three minutes and cooled to room temperature and the GC column was cooled to room temperature.

This procedure applied to the handling of calibration standards, USEPA reference samples, system blanks and project samples.

APPENDIX C

QUALITY ASSURANCE DATA FOR PURGEABLE HALOCARBONS

The data presented here were generated as part of the quality assurance program discussed in Section 5. The analytical procedure employed for purgeable halocarbons is detailed in Appendix B. Interpretation of project purgeable halocarbon data presented in Sections 6 and 7 was, in part, based on this quality assurance data.

TABLE C-1. SIGNIFICANCE OF CHLOROFORM DATA
PURGEABLE HALOCARBONS, GC/HALL DETECTOR
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Reproducibility of USEPA Standards				
True value, ug/L	9.13	10.1	68.5	74.6
Blank corrected mean of standard run as unknown, ug/L	10.0	10.9	70.9	81.7
Mean blank, ug/L	0.15			
Relative error from true value, % (accuracy)	+ 10	+ 7	+ 4	+ 10
Standard deviation about mean, % (precision)	± 14	± 1	± 14	± 1
Number of tests	8	2	83	2

Reproducibility of Laboratory Standards								
True value, ug/L	0.1	0.25	0.5	0.1 - 0.5	1.0	10	100	200
Blank corrected mean of standard run as unknown, ug/L	0.11	0.21	0.42		0.94	9.4	102	196
Mean blank, ug/L	0.04	0.04					<0.1	<0.1
Relative error from true value, % (accuracy)	+ 10	- 16	- 16	- 9	- 6	- 6	+ 2	- 2
Standard deviation about mean, % (precision)	± 55	± 10	± 8	± 22	± 9	± 20	± 3	± 8
Number of tests	5	5	8	18	8	57	3	3

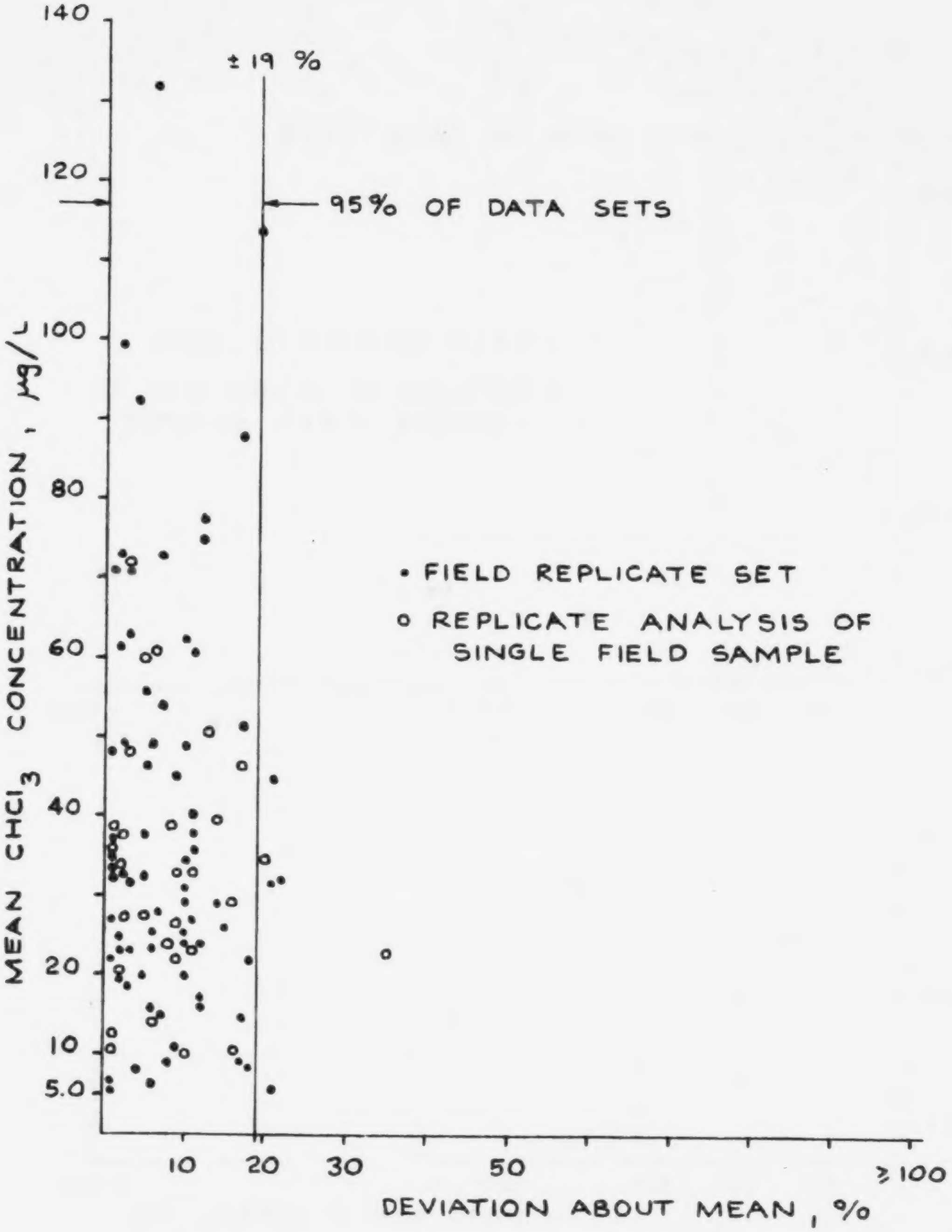


Figure C-1. Precision of instantaneous chloroform data.

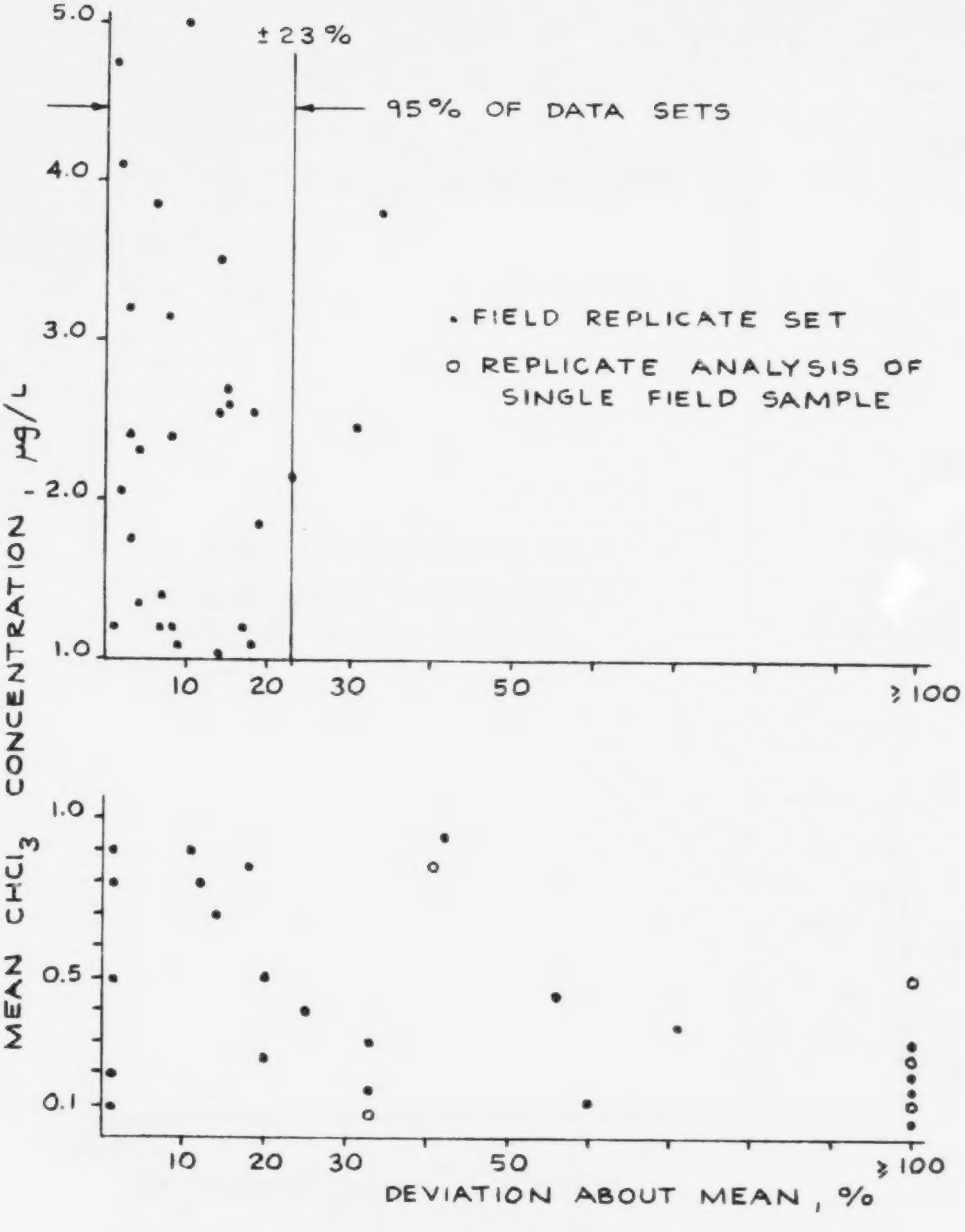


Figure C-2. Precision of instantaneous chloroform data.

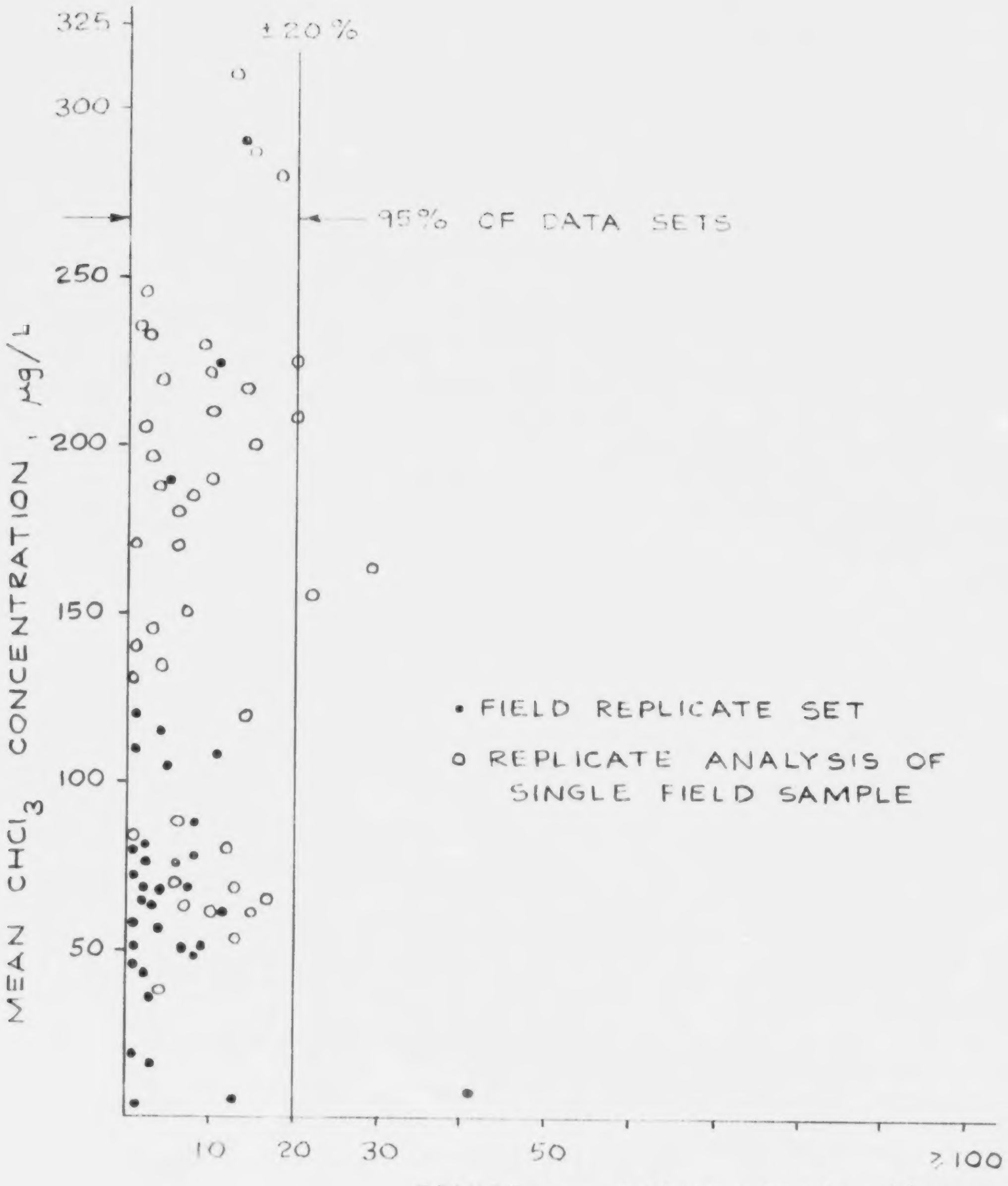


Figure C-3. Precision of terminal chloroform data.

TABLE C-2. SIGNIFICANCE OF BROMODICHLOROMETHANE DATA
PURGEABLE HALOCARBONS, GC/HALL DETECTOR
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Reproducibility of USEPA Standards				
True value, ug/L	0.8	1.19	9.2	11.6
Blank corrected mean of standard run as unknown, ug/L	0.64	1.97	9.3	16.2
Mean blank, ug/L		ND		
Relative error from true value, % (accuracy)	- 20	+ 65	+ 1	+ 36
Standard deviation about mean, % (precision)	± 2	± 11	± 0	± 19
Number of tests	2	8	2	83

Reproducibility of Laboratory Standards								
True value, ug/L	0.1	0.25	0.5	0.1 - 0.5	1.0	10	50	
Blank corrected mean of standard run as unknown, ug/L	0.08	0.21	0.42		0.98	9.4	53.5	
Mean blank, ug/L	ND	ND	ND		ND		ND	
Relative error from true value, % (accuracy)	- 20	- 16	- 16	- 13	- 2	- 6	+ 7	
Standard deviation about mean, % (precision)	± 13	± 10	± 7	± 10	± 6	± 19	± 8	
Number of tests	5	5	8	18	8	57	6	

ND = not detected

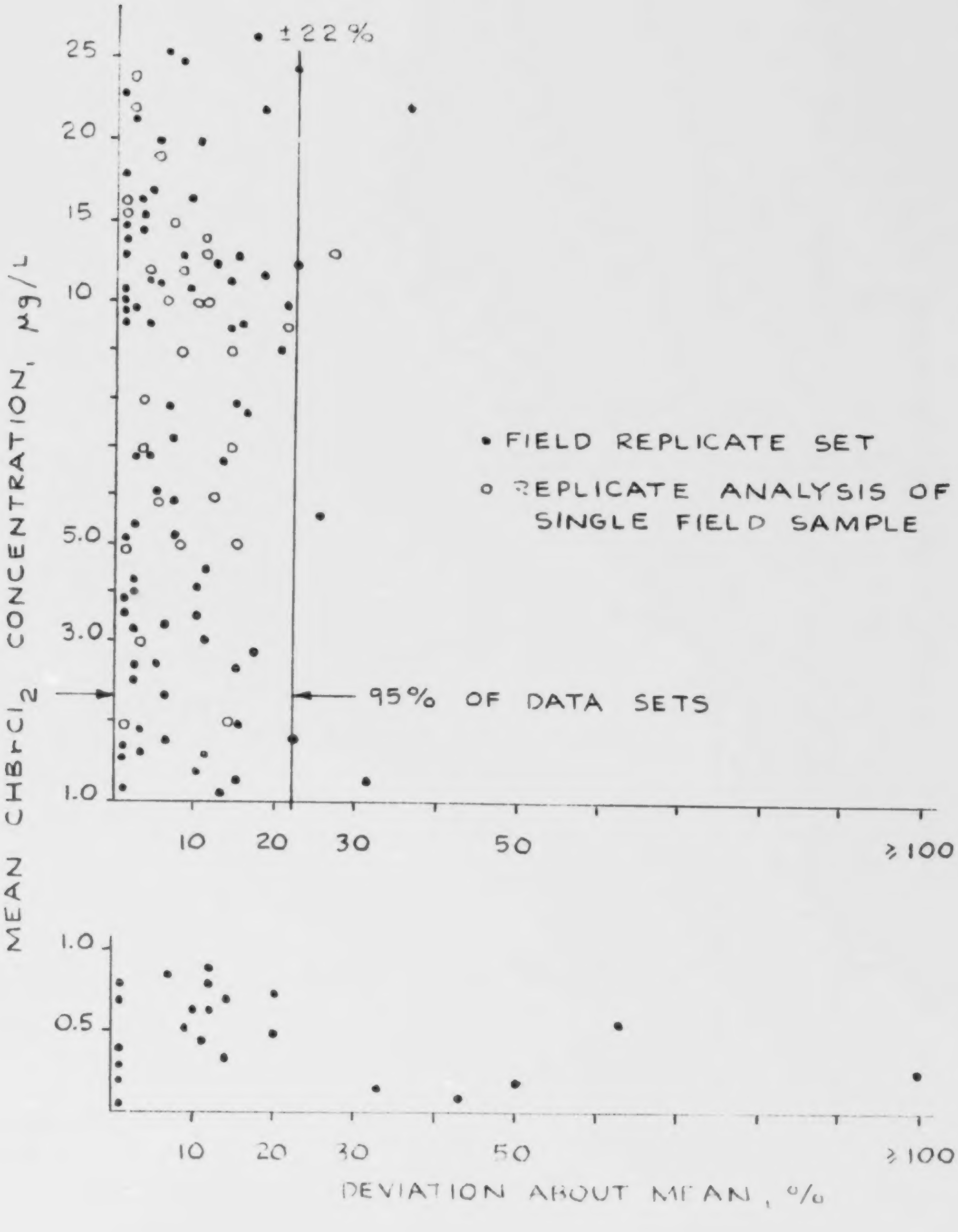


Figure C-4. Precision of instantaneous bromodichloromethane data.

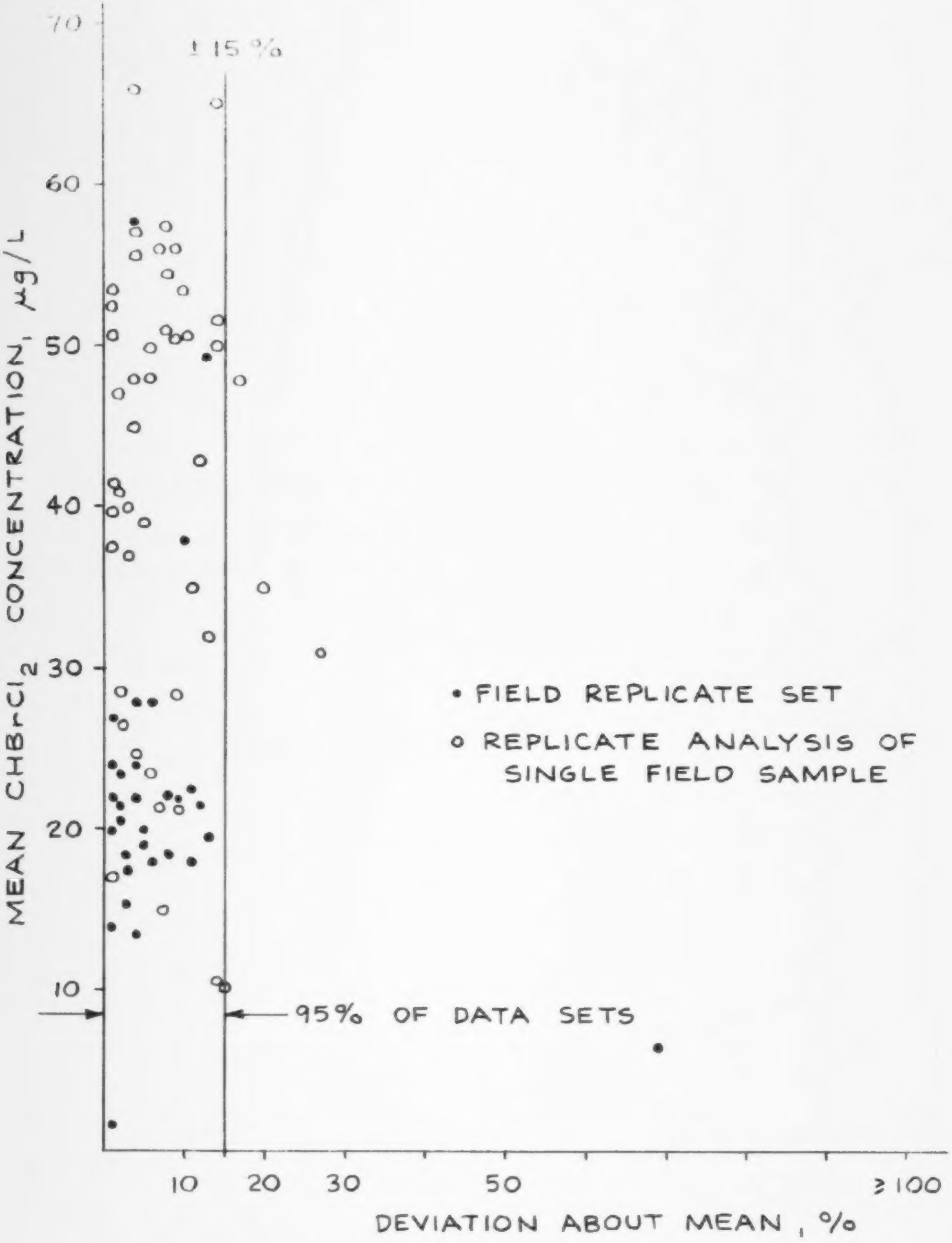


Figure C-5. Precision of terminal bromodichloromethane data.

TABLE C-3. SIGNIFICANCE OF DATA FOR DIBROMOCHLOROMETHANE AND/OR
CIS-1,3-DICHLOROPROPENE AND/OR 1,1,2-TRICHLOROETHANE
PURGEABLE HALOCARBONS, GC/HALL DETECTOR
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Reproducibility of USEPA Standards[a]				
True value, ug/L	1.0	2.74	7.1	17.2
Blank corrected mean of standard run as unknown, ug/L	0.80	1.87	6.7	14.4
Mean blank, ug/L		ND		
Relative error from true value, % (accuracy)	- 20	- 32	- 6	- 16
Standard deviation about mean, % (precision)	± 1	± 9	± 1	± 25
Number of tests	2	8	2	83

Reproducibility of Laboratory Standards[b]									
True value, ug/L	0.38	0.96	1.5	1.92	3.0	3.85	20[a]	38.5	
Blank corrected mean of standard run as unknown, ug/L	0.30	0.84	1.47	1.74	3.23	3.52	21.0	36.8	
Mean blank, ug/L	ND	ND	ND	ND	ND	ND	ND		
Relative error from true value, % (accuracy)	- 21	- 13	- 2	- 9	+ 8	- 9	+ 5	- 4	
Standard deviation about mean, % (precision)	± 7	± 8	± 2	± 7	± 4	± 5	± 6	± 13	
Number of tests	5	5	3	5	3	5	6	55	

ND = not detected

[a] for dibromochloromethane but based on co-eluting standards

[b] three compounds unless noted

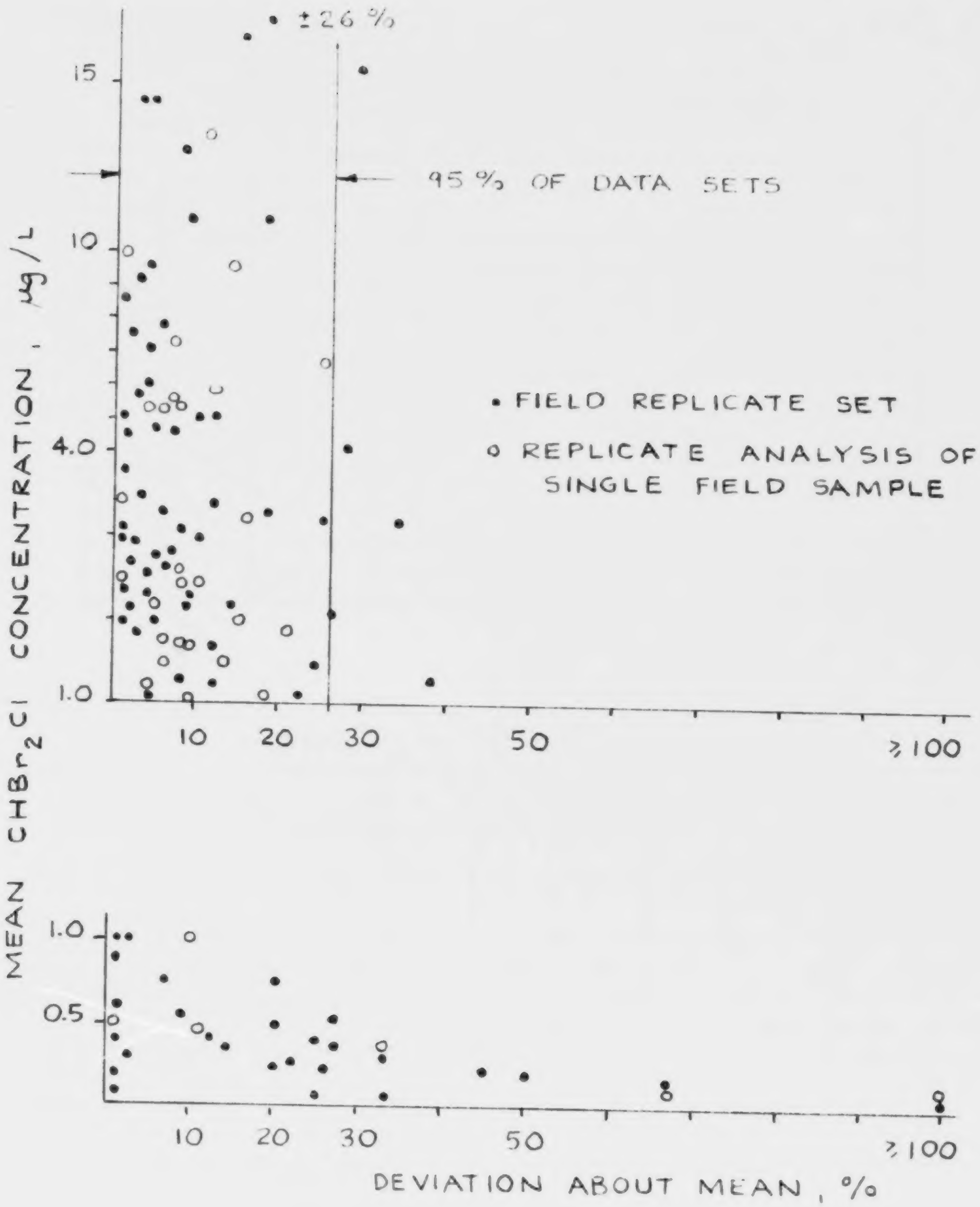


Figure C-6. Precision of instantaneous dibromochloromethane data.

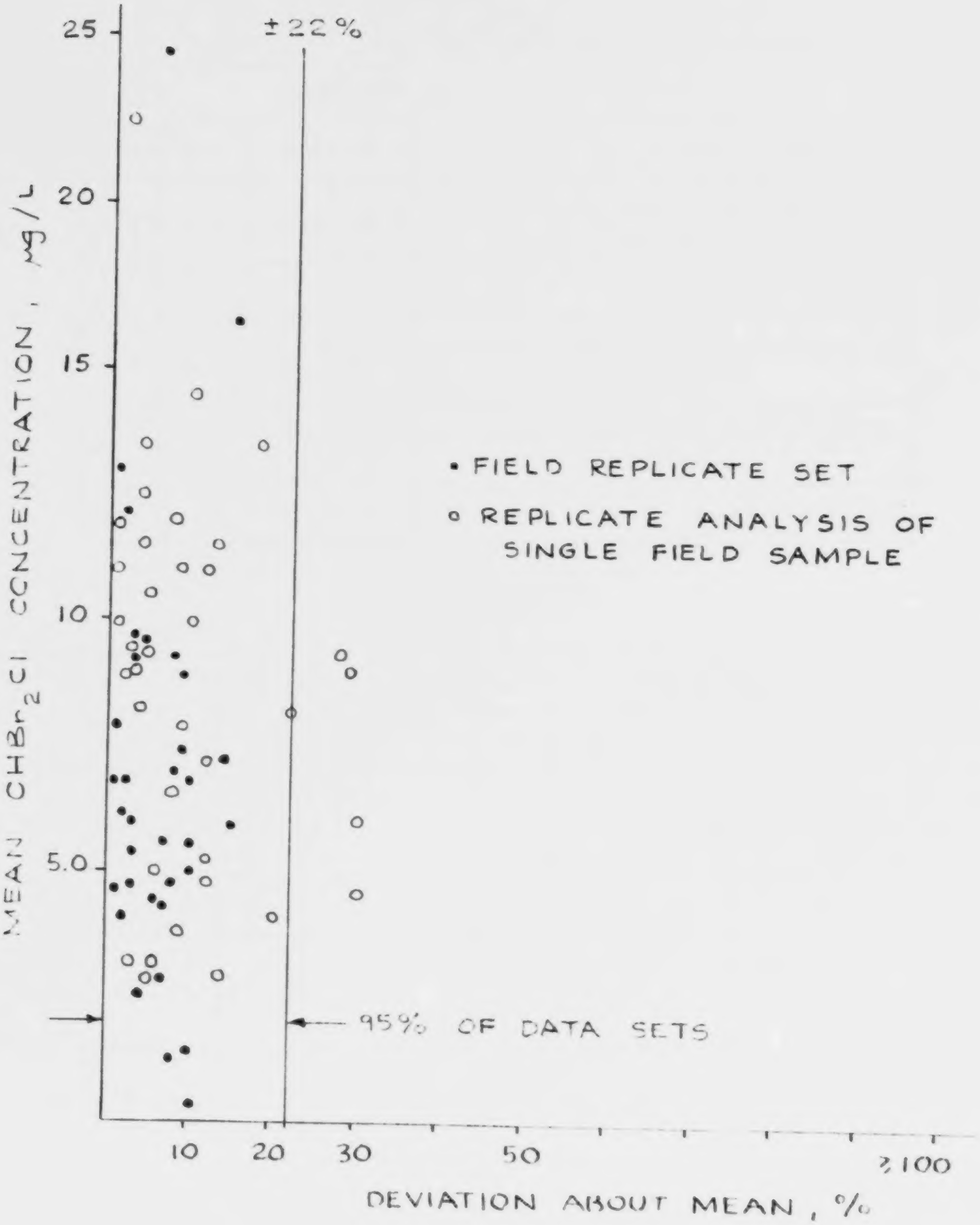


Figure C-7. Precision of terminal dibromochloromethane data.

TABLE C-4. SIGNIFICANCE OF BROMOFORM DATA
PURGEABLE HALOCARBONS, GC/HALL DETECTOR
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Reproducibility of USEPA Standards				
True value, ug/L	2.85	4.8	9.2	14.2
Blank corrected mean of standard run as unknown, ug/L	2.35	4.76	10.2	14.8
Mean blank, ug/L	ND			
Relative error from true value, % (accuracy)	- 18	- 1	+ 11	+ 4
Standard deviation about mean, % (precision)	± 11	± 1	± 2	± 20
Number of tests	8	2	2	83

Reproducibility of Laboratory Standards								
True value, ug/L	0.1	0.25	0.5		1.0	5.0	10	
Blank corrected mean of standard run as unknown, ug/L	<0.1	0.17	0.33		0.77	4.73	9.8	
Mean blank, ug/L	ND	ND	ND		ND	ND	ND	
Relative error from true value, % (accuracy)		- 32	- 34		- 23	- 5	- 2	
Standard deviation about mean, % (precision)		± 12	± 36		± 7	± 5	± 13	
Number of tests	5	5	8		8	6	57	

ND = not detected

TABLE C-5. SIGNIFICANCE OF CARBON TETRACHLORIDE DATA
PURGEABLE HALOCARBONS, GC/HALL DETECTOR
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Reproducibility of USEPA Standards				
True value, ug/L	1.68	1.9	3.9	12.6
Blank corrected mean of standard run as unknown, ug/L	1.32	1.83	3.85	11.8
Mean blank, ug/L	ND			
Relative error from true value, % (accuracy)	- 21	- 4	- 1	- 6
Standard deviation about mean, % (precision)	± 35	± 1	± 1	± 33
Number of tests	8	2	2	83

Reproducibility of Laboratory Standards								
True value, ug/L	0.1	0.25	0.5	0.1 - 0.5	1.0	10		
Blank corrected mean of standard run as unknown, ug/L	0.08	0.20	0.38		0.87	10.1		
Mean blank, ug/L	ND	ND	ND		ND			
Relative error from true value, % (accuracy)	- 20	- 20	- 24	+ 22	- 13	+ 1		
Standard deviation about mean, % (precision)	± 50	± 10	± 6	± 19	± 14	± 23		
Number of tests	5	5	8	18	8	56		

ND = not detected

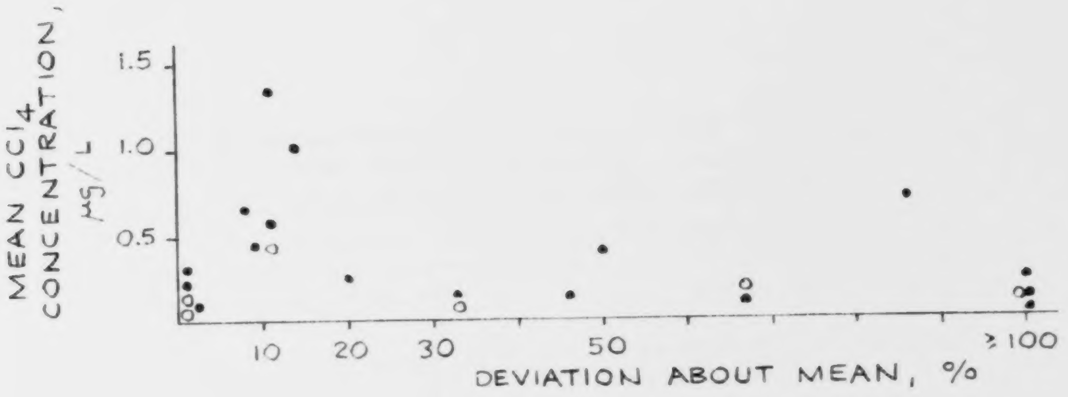


Figure C-8. Precision of instantaneous carbon tetrachloride data.

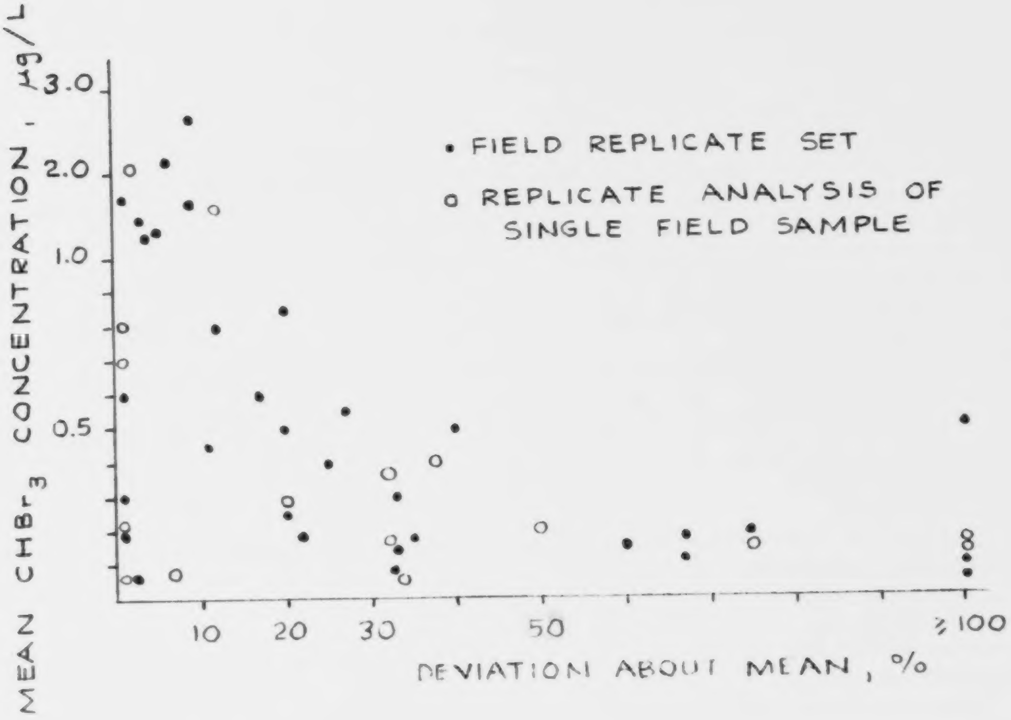


Figure C-9. Precision of instantaneous bromoform data.

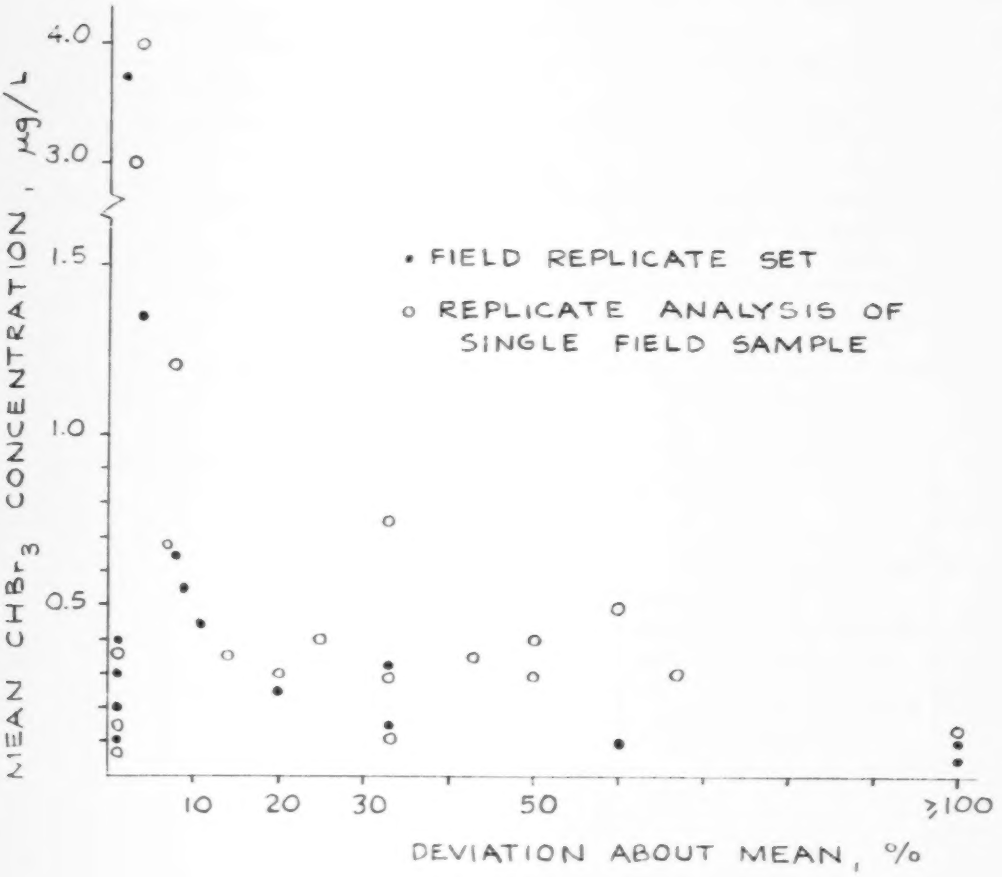


Figure C-10. Precision of terminal bromoform data.

TABLE C-6. SIGNIFICANCE OF DICHLOROIODOMETHANE DATA
PURGEABLE HALOCARBONS, GC/HALL DETECTOR
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Precision Indicated by Field Replicate Data Sets			
Range, ug/L	<0.1	0.1 - 0.2	1.0
Number of sets where mean lies in range	44	12	1
Standard deviation about mean, %	± 81	± 40	± 10

Precision Indicated by Replicate Analyses of Single Field Sample			
Range, ug/L	<0.1	0.15	>0.15
Number of sets where mean lies in range	13	1	0
Standard deviation about mean, %	± 101	± 100	

TABLE C-7. SIGNIFICANCE OF CHLOROBENZENE DATA
PURGEABLE HALOCARBONS, GC/HALL DETECTOR
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Reproducibility of Laboratory Standards									
True Value, ug/L	0.1	0.25	0.5	1.0	10				
Blank corrected mean of standard run as unknown, ug/L	<0.1	0.20	0.44	0.86	9.7				
Mean blank, ug/L	ND	ND	ND	ND					
Relative error from true value, % (accuracy)		- 20	- 12	- 14	- 3				
Standard deviation about mean, % (precision)		± 10	± 11	± 5	± 37				
Number of tests	5	5	5	5	57				

ND = not detected

Precision Indicated by Field Replicate Data Sets			
Range, ug/L	<0.1	0.1 - 0.8	1.4 - 2.9
Number of sets where mean lies in range	7	6	6
Standard deviation about mean, %	± 100	± 59	± 29

Precision Indicated by Replicate Analyses of Single Field Sample			
Range, ug/L	0.1	>0.1	
Number of sets where mean lies in range	2	0	
Standard deviation about mean, %	± 100		

TABLE C-8. SIGNIFICANCE OF 1,1-DICHLOROETHANE DATA
PURGEABLE HALOCARBONS, GC/HALL DETECTOR
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Reproducibility of Laboratory Standards								
True Value, ug/L	0.1	0.25	0.5	0.1 - 0.5	1.0	10		
Blank corrected mean of standard run as unknown, ug/L	0.10	0.22	0.51		0.99	10.1		
Mean blank, ug/L	ND	ND	ND		ND	ND		
Relative error from true value, % (accuracy)	0	- 12	+ 2	- 4	- 1	+ 1		
Standard deviation about mean, % (precision)	± 20	± 23	± 12	± 18	± 26	± 20		
Number of tests	4	5	5	14	5	55		

ND = not detected

Precision Indicated by Field Replicate Data Sets			
Range, ug/L	<0.1	0.1 - 0.4	>0.4
Number of sets where mean lies in range	11	11	0
Standard deviation about mean, %	± 181	± 81	

Precision Indicated by Replicate Analyses of Single Field Sample			
Range, ug/L	≤0.1	>0.1	
Number of sets where mean lies in range	5	0	
Standard deviation about mean, %	± 60		

TABLE C-9. SIGNIFICANCE OF 1,2-DICHLOROETHANE DATA
PURGEABLE HALOCARBONS, GC/HALL DETECTOR
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Reproducibility of USEPA Standards				
True value, ug/L	1.0	1.39	3.1	27.2
Blank corrected mean of standard run as unknown, ug/L	0.87	1.80	3.2	34.1
Mean blank, ug/L		ND		
Relative error from true value, % (accuracy)	- 13	+ 29	+ 3	+ 25
Standard deviation about mean, % (precision)	± 1	± 16	± 2	± 16
Number of tests	2	8	2	83

Reproducibility of Laboratory Standards								
True value, ug/L	0.1	0.25	0.5	0.1 - 0.5	1.0	10		
Blank corrected mean of standard run as unknown, ug/L	0.15	0.32	0.41		0.97	9.7		
Mean blank, ug/L	ND	ND	ND		ND			
Relative error from true value, % (accuracy)	+ 50	+ 28	- 18	+ 14	- 3	- 3		
Standard deviation about mean, % (precision)	± 7	± 9	± 45	± 24	± 5	± 14		
Number of tests	5	5	8	18	8	56		

ND = not detected

TABLE C-10. SIGNIFICANCE OF 1,2-DICHLOROETHANE DATA
PURGEABLE HALOCARBONS, GC/HALL DETECTOR
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Precision Indicated by Field Replicate Data Sets			
Range, ug/L	<0.1	0.1 - 0.3	>0.3
Number of sets where mean lies in range	20	5	0
Standard deviation about mean, %	± 105	± 53	

Precision Indicated by Replicate Analyses of Single Field Sample			
Range, ug/L	≤0.1	>0.1	
Number of sets where mean lies in range	7	0	
Standard deviation about mean, %	± 100		

TABLE C-11. SIGNIFICANCE OF 1,2-DICHLOROPROPANE DATA
PURGEABLE HALOCARBONS, GC/HALL DETECTOR
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Reproducibility of Laboratory Standards								
True Value, ug/L	0.1	0.25	0.5	0.1 - 0.5	1.0	10		
Blank corrected mean of standard run as unknown, ug/L	0.07	0.21	0.44		0.89	9.3		
Mean blank, ug/L	ND	ND	ND		ND			
Relative error from true value, % (accuracy)	- 30	- 16	- 12	- 19	- 11	- 7		
Standard deviation about mean, % (precision)	± 29	± 10	± 7	± 15	± 7	± 19		
Number of tests	5	5	5	15	5	56		

ND = not detected

Precision Indicated by Field Replicate Data Sets			
Range, ug/L	≤0.2	>0.2	
Number of sets where mean lies in range	12	0	
Standard deviation about mean, %	± 89		

Precision Indicated by Replicate Analyses of Single Field Sample			
Range, ug/L	≤0.25	>0.25	
Number of sets where mean lies in range	2	0	
Standard deviation about mean, %	± 100		

TABLE C-12. SIGNIFICANCE OF TRANS-1,3-DICHLOROPROPENE DATA
PURGEABLE HALOCARBONS, GC/HALL DETECTOR
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Reproducibility of Laboratory Standards								
True Value, ug/L	0.1	0.25	0.5		1.0	10		
Blank corrected mean of standard run as unknown, ug/L	<0.1	0.19	0.40		0.83	9.4		
Mean blank, ug/L	ND	ND	ND		ND			
Relative error from true value, % (accuracy)		- 24	- 20		- 17	- 6		
Standard deviation about mean, % (precision)		± 11	± 10		± 8	± 16		
Number of tests	5	5	5		5	44		

ND = not detected

Precision Indicated by Field Replicate Data Sets			
Range, ug/L	<0.1	≥0.1	
Number of sets where mean lies in range	2	0	
Standard deviation about mean, %	± 100		

Precision Indicated by Replicate Analyses of Single Field Sample			
Range, ug/L	<0.1	≥0.1	
Number of sets where mean lies in range	0	0	
Standard deviation about mean, %			

TABLE C-13. SIGNIFICANCE OF 1,1,1-TRICHLOROETHANE DATA
PURGEABLE HALOCARBONS, GC/HALL DETECTOR
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Reproducibility of USEPA Standards				
True value, ug/L	11.2			
Blank corrected mean of standard run as unknown, ug/L	11.4			
Mean blank, ug/L				
Relative error from true value, % (accuracy)	+ 2			
Standard deviation about mean, % (precision)	± 29			
Number of tests	83			

Reproducibility of Laboratory Standards								
True value, ug/L	0.1	0.25	0.5	0.1 - 0.5	1.0	10		
Blank corrected mean of standard run as unknown, ug/L	0.60	0.65	0.73		1.08	10.1		
Mean blank, ug/L	0.04	0.04						
Relative error from true value, % (accuracy)	+ 500	+ 160	+ 46	+ 200	+ 8	+ 1		
Standard deviation about mean, % (precision)	± 25	± 34	± 10	± 21	± 12	± 23		
Number of tests	5	5	8	18	8	56		

TABLE C-14. SIGNIFICANCE OF TRICHLOROETHYLENE DATA
PURGEABLE HALOCARBONS, GC/HALL DETECTOR
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Reproducibility of USEPA Standards				
True value, ug/L	19.0			
Blank corrected mean of standard run as unknown, ug/L	19.9			
Mean blank, ug/L				
Relative error from true value, % (accuracy)	+ 5			
Standard deviation about mean, % (precision)	± 30			
Number of tests	83			

Reproducibility of Laboratory Standards								
True value, ug/L	0.17	0.43	0.82	0.86	0.17 - 0.86	1.64	1.74	17.4
Blank corrected mean of standard run as unknown, ug/L	0.29	0.52	0.65	1.18		1.44	2.16	16.5
Mean blank, ug/L	0.14	0.14	0.59	0.14		0.59	0.14	
Relative error from true value, % (accuracy)	+ 71	+ 21	- 21	+ 37	+ 32	- 12	+ 24	- 5
Standard deviation about mean, % (precision)	± 38	± 15	± 18	± 13	± 21	± 4	± 5	± 24
Number of tests	5	5	3	5	18	3	5	43

TABLE C-15. SIGNIFICANCE OF DATA FOR 1,1,2,2-TETRACHLOROETHANE AND/OR TETRACHLOROETHYLENE PURGEABLE HALOCARBONS, GC/HALL DETECTOR APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Reproducibility of USEPA Standards[a]				
True value, ug/L	8.8			
Blank corrected mean of standard run as unknown, ug/L	12.0			
Mean blank, ug/L				
Relative error from true value, % (accuracy)	+ 36			
Standard deviation about mean, % (precision)	± 32			
Number of tests	83			

Reproducibility of Laboratory Standards[b]								
True value, ug/L	0.14	0.35	0.42	0.70	0.84	0.14 - 0.84	1.41	14.1
Blank corrected mean of standard run as unknown, ug/L	0.13	0.27	0.19	0.61	0.54		1.23	13.8
Mean blank, ug/L	0.12	0.12	0.16	0.12	0.16		0.12	
Relative error from true value, % (accuracy)	- 7	- 23	- 55	- 13	- 36	- 23	- 13	- 2
Standard deviation about mean, % (precision)	± 31	± 15	± 5	± 11	± 13	± 17	± 11	± 25
Number of tests	5	5	3	5	3	21	5	53

[a] for tetrachloroethylene but based on co-eluting standards

[b] both compounds

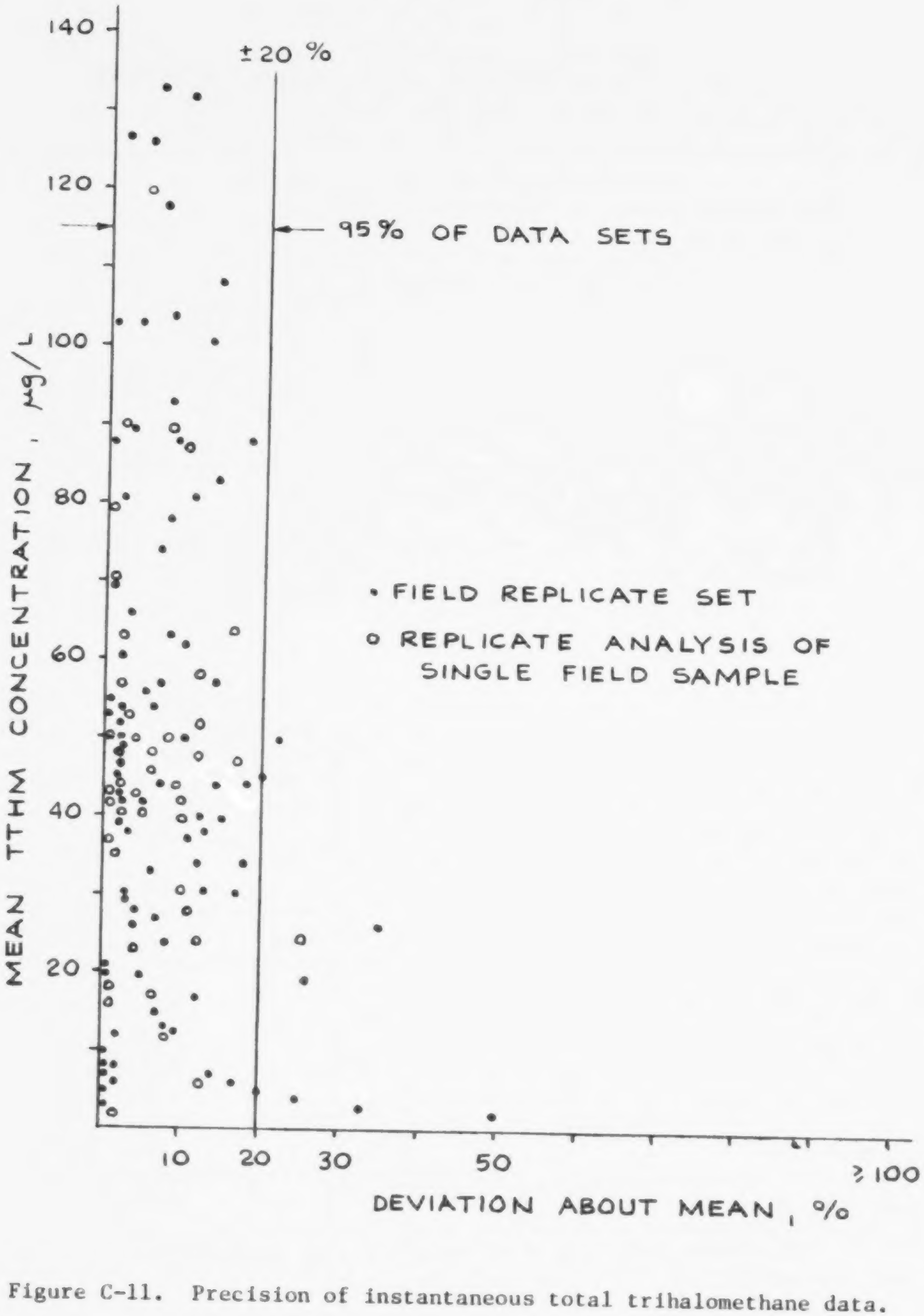


Figure C-11. Precision of instantaneous total trihalomethane data.

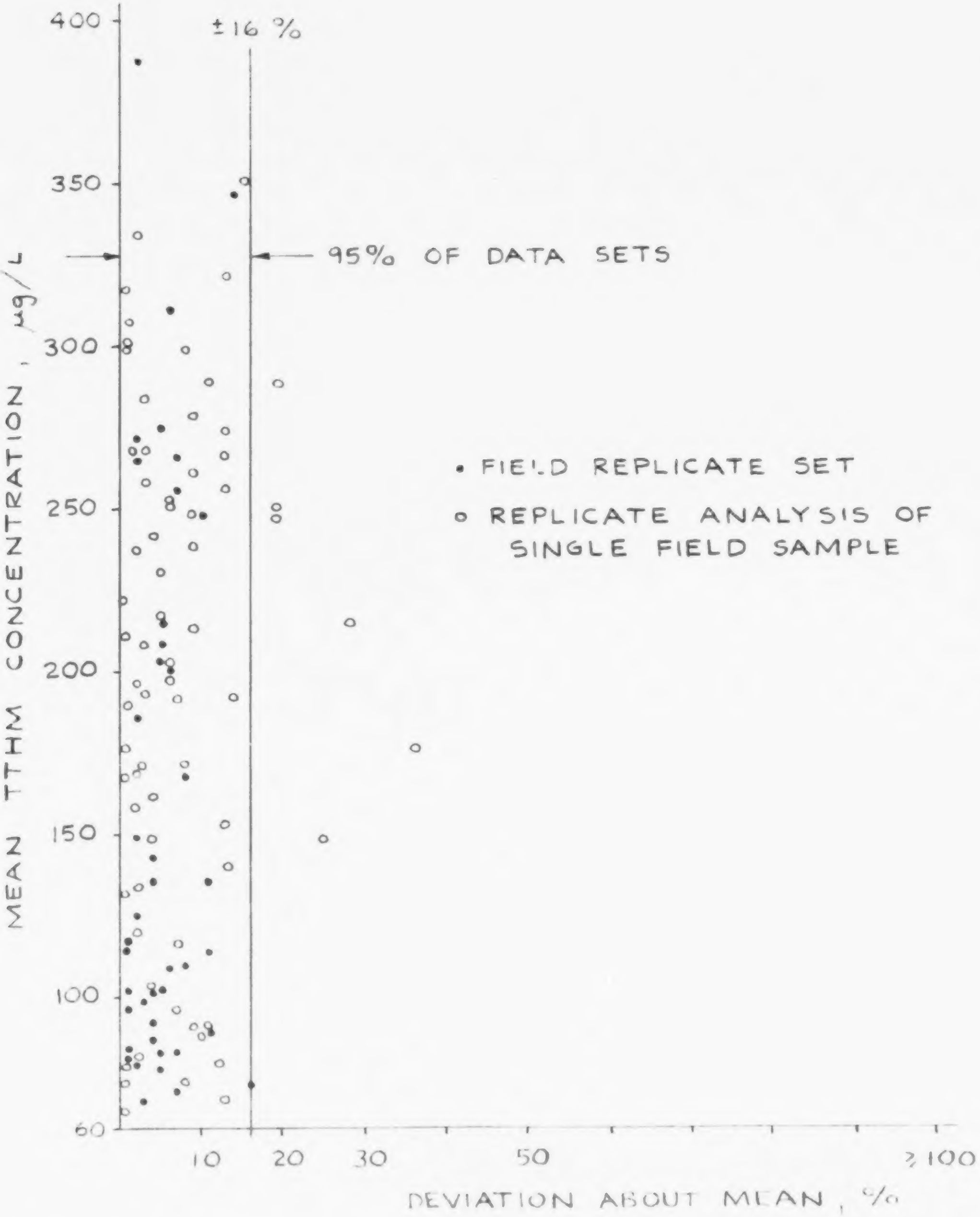


Figure C-12. Precision of terminal total trihalomethane data.

APPENDIX D

EQUIPMENT AND ANALYTICAL PROCEDURES FOR BASE-NEUTRAL EXTRACTABLE HYDROCARBONS

STANDARDS

Calibration standards were prepared gravimetrically according to the nature of the particular compound. Volatile liquids were weighed in a tared microsyringe to prevent evaporation during measurement. Solids were weighed in a tared beaker. Standard compounds of 99+% purity were used. Primary standard solutions at one part per thousand were made up in Burdick and Jackson distilled-in-glass quality solvents. Methylene chloride was used to solubilize the halogenated compounds. Methylene chloride was then exchanged for hexane in a Kuderna-Danish apparatus. The solvent exchange was carried out in three steps to insure that all methylene chloride was removed. Primary standard solutions of non-halogenated compounds were prepared in hexane with benzene occasionally being used to aid solubility. A secondary dilution from the primary stock was made in hexane to a ug/L working level and was stored in hypovials sealed with Teflon-lined septa for up to six months in a freezer. Internal standard hexachlorobenzene for the calibration standard was prepared in the same manner.

Prepared working level calibration standards of the base-neutral extractable compounds were examined by GC/MS. The presence and elution order of the project priority pollutants listed in Tables 5 and 6 were confirmed.

EQUIPMENT

The USEPA Priority Pollutant Protocol[8] for analysis of base-neutral extractable compounds by gas chromatography/mass spectrometry (GC/MS) was revised as necessary by the laboratory to enable routine analysis of concentrated sample extracts by GC/Hall detector (GC/Hall) and GC/flame ionization detector (GC/FID).[9]

A Tracor model 560 gas chromatograph equipped with a digital temperature programmer was interfaced to a Tracor model 700 Hall electrolytic conductivity detector and to a Tracor FI detector. Output from the system was integrated and recorded by a Hewlett Packard 3380A integrator.

PROCEDURE

The basic extraction and analysis procedures that were used are described in the USEPA's Protocol.[8] Several modifications were made by the laboratory as listed below:

1. Three liters of samples were extracted.

2. After adjusting the pH to greater than eleven, a methanol solution of hexachlorobenzene was added as an internal standard to each sample and solvent blank to be extracted.

3. The sample was serially extracted with one 250 mL portion and two 150 mL portions of distilled-in-glass methylene chloride.

4. After concentrating the volume of the combined methylene chloride extracts to one milliliter, 10 mL of distilled-in-glass hexane was added and the volume was again concentrated to 1.0 mL ± 0.05 mL.

Modifications made in the analysis of the halogenated base-neutral extractable Priority Pollutants were:

1. A Hall electrolytic conductivity detector operated in the halogen specific mode was used for detection of all halogen compounds in this fraction including the pesticides.

2. Nitrogen was the carrier gas at 40 cc/minute.

3. The GC column temperature was programmed, after an initial four minute hold at 50°C, from 50°C to 280°C at 8°C/minute, with a final fifteen minute hold.

Quantification by the HP 3380A integrator for both halogenated and non-halogeanted compounds was calculated as follows:

$$C_y = A_y \times R_y$$

where

Cy = concentration, ug/L, of compound y in sample
Ay = chromatographed area for compound y in sample
Ry = response factor for compound y in calibration

$$\text{Response factor} = \frac{\text{concentration, ug/L, in calibration}}{\text{chromatographed area in calibration}}$$

It should be noted that C is the concentration of the compound in the sample assuming 100% extraction efficiency.

APPENDIX E

QUALITY ASSURANCE DATA FOR EXTRACTABLE HALOCARBONS

The data presented here were generated as part of the quality assurance program discussed in Section 5. The analytical procedure employed for extractable halocarbons is detailed in Appendix D. Interpretation of project extractable halocarbon data presented in Sections 6 and 7 was based, in part, on this quality assurance data.

TABLE E-1. SIGNIFICANCE OF 1,4-DICHLOROBENZENE DATA BASE-NEUTRAL EXTRACTABLE HALOCARBON, GC/HALL DETECTOR[a]
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Extraction of Standards from Distilled Water		
Concentration, ug/L	0.17	1.67
Mean recovery, %	85	62
Standard deviation about mean, %	± 8	± 4
Number of tests[b]	2	1

Standard Reproducibility by Direct Injection			
True value, ug/L	0.42	1.67	
Mean of standard run as unknown, ug/L	0.36	1.72	
Relative error from true value, % (accuracy)	- 13	+ 3	
Standard deviation about mean, % (precision)	± 29	± 10	
Number of tests	3	37	

Precision of Field Data						
	Field Replicate Data Sets			Replicate Analysis of Single Field Sample		
Range, ug/L	<0.1	0.1-0.4	1.7	<0.1	0.1-0.9	1.3
Number of sets where mean lies in range	17	7	1	18	11	1
Standard deviation about mean, %	± 75	± 78	± 14	± 68	± 19	± 100

a = 3000 concentration factor
b = Each test performed in triplicate

TABLE E-2. SIGNIFICANCE OF 1,3-DICHLOROBENZENE DATA BASE-NEUTRAL EXTRACTABLE HALOCARBON, GC/HALL DETECTOR[a] APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Extraction of Standards from Distilled Water		
Concentration, ug/L	0.17	1.67
Mean recovery, %	63	55
Standard deviation about mean, %	± 11	± 4
Number of tests[b]	2	1

Standard Reproducibility by Direct Injection			
True value, ug/L	0.42	1.67	
Mean of standard run as unknown, ug/L	0.35	1.72	
Relative error from true value, % (accuracy)	- 17	+ 3	
Standard deviation about mean, % (precision)	± 28	± 9	
Number of tests	3	37	

Precision of Field Data						
	Field Replicate Data Sets			Replicate Analysis of Single Field Sample		
Range, ug/L	<0.1	0.1-0.3	1.3-3.3	<0.1	0.5	>0.5
Number of sets where mean lies in range	4	3	3	7	2	0
Standard deviation about mean, %	± 107	± 100	± 72	± 111	± 58	

a = 3000 concentration factor

b = Each test performed in triplicate

TABLE E-3. SIGNIFICANCE OF 1,2-DICHLOROBENZENE AND/OR HEXACHLOROETHANE DATA BASE-NEUTRAL EXTRACTABLE HALOCARBON, GC/HALL DETECTOR[a] APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Extraction of Both Standards from Distilled Water		
Concentration, ug/L	0.33	0.33
Mean recovery, %	57	71
Standard deviation about mean, %	± 6	± 1
Number of tests[b]	2	1

Reproducibility of Both Standards by Direct Injection			
True value, ug/L	0.83	3.33	
Mean of standard run as unknown, ug/L	0.88	3.42	
Relative error from true value, % (accuracy)	+ 6	+ 3	
Standard deviation about mean, % (precision)	± 23	± 8	
Number of tests	3	37	

Precision of Field Data						
	Field Replicate Data Sets			Replicate Analysis of Single Field Sample		
Range, ug/L	<0.1	0.1-0.6	1.1	<0.1	0.1-0.5	>0.5
Number of sets where mean lies in range	9	4	1	13	7	0
Standard deviation about mean, %	± 82	± 93	± 5	± 53	± 3	

a = 3000 concentration factor

b = Each test performed in triplicate

TABLE E-4. SIGNIFICANCE OF 1,2,4-TRICHLOROBENZENE AND/OR HEXACHLOROBUTADIENE DATA
BASE-NEUTRAL EXTRACTABLE HALOCARBON, GC/HALL DETECTOR[a]
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Extraction of Both Standards from Distilled Water		
Concentration, ug/L	0.33	3.33
Mean recovery, %	61	31
Standard deviation about mean, %	± 15	± 5
Number of tests[b]	2	1

Reproducibility of Both Standards by Direct Injection			
True value, ug/L	0.83	3.33	
Mean of standard run as unknown, ug/L	0.84	3.52	
Relative error from true value, % (accuracy)	+ 1	+ 6	
Standard deviation about mean, % (precision)	± 16	± 10	
Number of tests	3	37	

Precision of Field Data						
	Field Replicate Data Sets			Replicate Analysis of Single Field Sample		
Range, ug/L	<0.1	0.1-0.3	>0.3	<0.1	0.1-0.6	>0.6
Number of sets where mean lies in range	7	4	0	7	5	0
Standard deviation about mean, %	± 77	± 54		± 68	± 13	

a = 3000 concentration factor
b = Each test performed in triplicate

TABLE E-5. SIGNIFICANCE OF BIS(2-CHLOROISOPROPYL) ETHER AND/OR BIS(2-CHLOROETHYL) ETHER DATA

BASE-NEUTRAL EXTRACTABLE HALOCARBON, GC/HALL DETECTOR[a]
APPROXIMATE LOWER DETECTION LEVEL = 0.2 ug/L

Extraction of Both Standards from Distilled Water[b]		
Concentration, ug/L	0.33	3.33
Mean recovery, %	56	84
Standard deviation about mean, %	± 24	± 8
Number of tests[c]	2	1

Reproducibility of Both Standards by Direct Injection			
True value, ug/L	0.83	3.33	
Mean of standard run as unknown, ug/L	0.28	3.59	
Relative error from true value, % (accuracy)	66	+ 8	
Standard deviation about mean, % (precision)	± 26	± 10	
Number of tests	3	37	

a = 3000 concentration factor
b = Blank corrected. See Appendix G.
c = Each test performed in triplicate

There were no field replicate data sets or replicate analyses data sets in which these compounds were detected.

TABLE E-6. SIGNIFICANCE OF BIS(2-CHLOROETHOXY) METHANE DATA
BASE-NEUTRAL EXTRACTABLE HALOCARBON, GC/HALL DETECTOR[a]
APPROXIMATE LOWER DETECTION LEVEL = 0.1-0.2 ug/L

Extraction of Standards from Distilled Water		
Concentration, ug/L	0.17	1.67
Mean recovery, %	49	63
Standard deviation about mean, %	± 51	± 6
Number of tests[b]	2	1

Standard Reproducibility by Direct Injection			
True value, ug/L	0.42	1.67	
Mean of standard run as unknown, ug/L	0.39	1.80	
Relative error from true value, % (accuracy)	- 6	+ 8	
Standard deviation about mean, % (precision)	± 8	± 10	
Number of tests	3	37	

Precision of Field Data						
	Field Replicate Data Sets			Replicate Analysis of Single Field Sample		
Range, ug/L	<0.1	≥0.1		<0.1	0.1-0.2	>0.2
Number of sets where mean lies in range	5	0		9	3	0
Standard deviation about mean, %	± 71			± 98	± 20	

a = 3000 concentration factor
b = Each test performed in triplicate

TABLE E-7. SIGNIFICANCE OF HEXACHLOROCYCLOPENTADIENE DATA
BASE-NEUTRAL EXTRACTABLE HALOCARBON, GC/HALL DETECTOR[a]
APPROXIMATE LOWER DETECTION LEVEL = 0.1-0.2 ug/L

Extraction of Standards from Distilled Water		
Concentration, ug/L	0.17	1.67
Mean recovery, %	56	26
Standard deviation about mean, %	± 36	± 5
Number of tests[b]	2	1

Standard Reproducibility by Direct Injection			
True value, ug/L	0.42	1.67	
Mean of standard run as unknown, ug/L	0.33	1.74	
Relative error from true value, % (accuracy)	- 21	+ 5	
Standard deviation about mean, % (precision)	± 16	± 13	
Number of tests	3	37	

Precision of Field Data						
	Field Replicate Data Sets			Replicate Analysis of Single Field Sample		
Range, ug/L	<0.1	≥0.1		≤0.1	>0.1	
Number of sets where mean lies in range	1	0		6	0	
Standard deviation about mean, %	± 150			± 100		

a = 3000 concentration factor

b = Each test performed in triplicate

TABLE E-8. SIGNIFICANCE OF 2-CHLORONAPHTHALENE DATA BASE-NEUTRAL EXTRACTABLE HALOCARBON, GC/HALL DETECTOR[a] APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Extraction of Standards from Distilled Water		
Concentration, ug/L	0.17	1.67
Mean recovery, %	50	53
Standard deviation about mean, %	± 22	± 3
Number of tests[b]	2	1

Standard Reproducibility by Direct Injection			
True value, ug/L	0.42	1.67	
Mean of standard run as unknown, ug/L	0.37	1.73	
Relative error from true value, % (accuracy)	- 12	+ 4	
Standard deviation about mean, % (precision)	± 3	± 16	
Number of tests	3	37	

Precision of Field Data						
	Field Replicate Data Sets			Replicate Analysis of Single Field Sample		
Range, ug/L	0.1-0.4	>0.4		<0.1	0.1-1.3	
Number of sets where mean lies in range	5	0		2	12	
Standard deviation about mean, %	± 21			± 100	± 27	

a = 3000 concentration factor

b = Each test performed in triplicate

TABLE E-9. SIGNIFICANCE OF 4-CHLOROPHENYL PHENYL ETHER DATA
BASE-NEUTRAL EXTRACTABLE HALOCARBON, GC/HALL DETECTOR[a]
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Extraction of Standards from Distilled Water		
Concentration, ug/L	0.17	1.67
Mean recovery, %	55	63
Standard deviation about mean, %	± 17	± 3
Number of tests[b]	2	1

Standard Reproducibility by Direct Injection			
True value, ug/L	0.42	1.67	
Mean of standard run as unknown, ug/L	0.39	1.72	
Relative error from true value, % (accuracy)	- 6	+ 3	
Standard deviation about mean, % (precision)	± 11	± 14	
Number of tests	3	37	

Precision of Field Data						
	Field Replicate Data Sets			Replicate Analysis of Single Field Sample		
Range, ug/L	<0.1	≥0.1		<0.1	0.2	>0.2
Number of sets where mean lies in range	2	0		4	1	0
Standard deviation about mean, %	± 67			± 100	± 100	

a = 3000 concentration factor
b = Each test performed in triplicate

TABLE E-10. SIGNIFICANCE OF 4-BROMOPHENYL PHENYL ETHER AND/OR α-BHC DATA BASE-NEUTRAL EXTRACTABLE HALOCARBON, GC/HALL DETECTOR[a] APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Extraction of Both Standards from Distilled Water		
Concentration, ug/L	0.33	3.33
Mean recovery, %	83	68
Standard deviation about mean, %	± 8	± 2
Number of tests[b]	2	1

Reproducibility of Both Standards by Direct Injection			
True value, ug/L	0.83	3.33	
Mean of standard run as unknown, ug/L	0.63	3.50	
Relative error from true value, % (accuracy)	- 24	+ 5	
Standard deviation about mean, % (precision)	± 10	± 11	
Number of tests	3	37	

Precision of Field Data						
	Field Replicate Data Sets			Replicate Analysis of Single Field Sample		
Range, ug/L	<0.1	≥0.1		<0.1	≥0.1	
Number of sets where mean lies in range	1	0		1	0	
Standard deviation about mean, %	± 0			± 100		

a = 3000 concentration factor
b = Each test performed in triplicate

TABLE E-11. SIGNIFICANCE OF γ-BHC (LINDANE) AND/OR δ-BHC DATA BASE-NEUTRAL EXTRACTABLE HALOCARBON, GC/HALL DETECTOR[a]

APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Extraction of Standards from Distilled Water		
Concentration, ug/L	0.33	3.33
Mean recovery, %	55	61
Standard deviation about mean, %	± 6	± 4
Number of tests[b]	2	1

Standard Reproducibility by Direct Injection			
True value, ug/L	0.83	3.33	
Mean of standard run as unknown, ug/L	0.71	3.49	
Relative error from true value, % (accuracy)	- 14	+ 5	
Standard deviation about mean, % (precision)	± 10	± 10	
Number of tests	3	37	

Precision of Field Data						
	Field Replicate Data Sets			Replicate Analysis of Single Field Sample		
Range, ug/L	<0.1	≥0.1		<0.1	≥0.1	
Number of sets where mean lies in range	4	0		5	0	
Standard deviation about mean, %	± 60			± 40		

a = 3000 concentration factor

b = Each test performed in triplicate

TABLE E-12. SIGNIFICANCE OF HEPTACHLOR AND/OR β-BHC DATA BASE-NEUTRAL EXTRACTABLE HALOCARBON, GC/HALL DETECTOR[a] APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Extraction of Both Standards from Distilled Water		
Concentration, ug/L	0.33	3.33
Mean recovery, %	57	61
Standard deviation about mean, %	± 4	± 4
Number of tests[b]	2	1

Reproducibility of Both Standards by Direct Injection			
True value, ug/L	0.83	3.33	
Mean of standard run as unknown, ug/L	0.74	3.46	
Relative error from true value, % (accuracy)	- 11	+ 4	
Standard deviation about mean, % (precision)	± 3	± 11	
Number of tests	3	37	

Precision of Field Data						
	Field Replicate Data Sets			Replicate Analysis of Single Field Sample		
Range, ug/L	<0.1	0.1-0.4	>0.4	<0.1	0.1-0.4	>0.4
Number of sets where mean lies in range	8	5	0	13	2	0
Standard deviation about mean, %	± 61	± 45		± 73	± 57	

a = 3000 concentration factor

b = Each test performed in triplicate

TABLE E-13. SIGNIFICANCE OF ALDRIN DATA
BASE-NEUTRAL EXTRACTABLE HALOCARBON, GC/HALL DETECTOR[a]
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Extraction of Standards from Distilled Water		
Concentration, ug/L	0.17	1.67
Mean recovery, %	55	63
Standard deviation about mean, %	± 17	± 3
Number of tests[b]	2	1

Standard Reproducibility by Direct Injection			
True value, ug/L	0.42	1.67	
Mean of standard run as unknown, ug/L	0.35	1.77	
Relative error from true value, % (accuracy)	- 17	+ 6	
Standard deviation about mean, % (precision)	± 6	± 11	
Number of tests	3	37	

Precision of Field Data						
	Field Replicate Data Sets			Replicate Analysis of Single Field Sample		
Range, ug/L	<0.1	0.1-0.9	>0.9	<0.1	0.1-0.3	>0.3
Number of sets where mean lies in range	10	6	0	5	4	0
Standard deviation about mean, %	± 60	± 21		± 79	± 18	

a = 3000 concentration factor
b = Each test performed in triplicate

TABLE E-14. SIGNIFICANCE OF HEPTACHLOR EPOXIDE DATA
BASE-NEUTRAL EXTRACTABLE HALOCARBON, GC/HALL DETECTOR[a]
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Extraction of Standards from Distilled Water		
Concentration, ug/L	0.17	1.67
Mean recovery, %	75	57
Standard deviation about mean, %	± 16	± 2
Number of tests[b]	2	1

Standard Reproducibility by Direct Injection			
True value, ug/L	0.42	1.67	
Mean of standard run as unknown, ug/L	0.39	1.73	
Relative error from true value, % (accuracy)	- 7	+ 4	
Standard deviation about mean, % (precision)	± 9	± 9	
Number of tests	3	37	

Precision of Field Data						
	Field Replicate Data Sets			Replicate Analysis of Single Field Sample		
Range, ug/L	<0.1	≥0.1		<0.1	≥0.1	
Number of sets where mean lies in range	1	0		2	0	
Standard deviation about mean, %	± 61			± 155		

a = 3000 concentration factor

b = Each test performed in triplicate

TABLE E-15. SIGNIFICANCE OF α-ENDOSULFAN DATA
BASE-NEUTRAL EXTRACTABLE HALOCARBON, GC/HALL DETECTOR[a]
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Extraction of Standards from Distilled Water		
Concentration, ug/L	0.17	1.67
Mean recovery, %	7	10
Standard deviation about mean, %	± 11	± 4
Number of tests[b]	2	1

Standard Reproducibility by Direct Injection			
True value, ug/L	0.17	0.42	1.67
Mean of standard run as unknown, ug/L	0.11	0.42	1.73
Relative error from true value, % (accuracy)	- 35	+ 1	+ 4
Standard deviation about mean, % (precision)	± 1	± 21	± 10
Number of tests	3	3	37

Precision of Field Data						
	Field Replicate Data Sets			Replicate Analysis of Single Field Sample		
Range, ug/L	<0.1	0.2	>0.2	<0.1	0.1	>0.1
Number of sets where mean lies in range	7	1	0	18	1	0
Standard deviation about mean, %	± 82	± 35		± 80	± 0	

a = 3000 concentration factor

b = Each test performed in triplicate

TABLE E-16. SIGNIFICANCE OF DDT DATA
BASE-NEUTRAL EXTRACTABLE HALOCARBON, GC/HALL DETECTOR[a]
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Extraction of Standards from Distilled Water		
Concentration, ug/L	0.17	1.67
Mean recovery, %	49	52
Standard deviation about mean, %	± 11	± 13
Number of tests[b]	2	1

Standard Reproducibility by Direct Injection			
True value, ug/L	0.42	1.67	
Mean of standard run as unknown, ug/L	0.33	1.73	
Relative error from true value, % (accuracy)	- 21	+ 4	
Standard deviation about mean, % (precision)	± 12	± 20	
Number of tests	3	37	

Precision of Field Data						
	Field Replicate Data Sets			Replicate Analysis of Single Field Sample		
Range, ug/L	<0.1	0.1	>0.1	<0.1	≥0.1	
Number of sets where mean lies in range	1	1	0	1	0	
Standard deviation about mean, %	± 100	± 100		± 170		

a = 3000 concentration factor

b = Each test performed in triplicate

TABLE E-17. SIGNIFICANCE OF DIELDRIN AND DDE DATA BASE-NEUTRAL EXTRACTABLE HALOCARBON, GC/HALL DETECTOR[a] APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Extraction of Both Standards from Distilled Water		
Concentration, ug/L	0.17	1.67
Mean recovery, %	62	58
Standard deviation about mean, %	± 12	± 4
Number of tests[b]	2	1

Reproducibility of Both Standards by Direct Injection			
True value, ug/L	0.83	3.33	
Mean of standard run as unknown, ug/L	0.77	3.45	
Relative error from true value, % (accuracy)	- 7	+ 4	
Standard deviation about mean, % (precision)	± 8	± 9	
Number of tests	3	37	

a = 3000 concentration factor
b = Each test performed in triplicate

There were no field replicate data sets or replicate analyses data sets in which these compounds were detected.

TABLE E-18. SIGNIFICANCE OF ENDRIN DATA
BASE-NEUTRAL EXTRACTABLE HALOCARBON, GC/HALL DETECTOR[a]
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Extraction of Standards from Distilled Water		
Concentration, ug/L	0.17	1.67
Mean recovery, %	67	70
Standard deviation about mean, %	± 18	± 10
Number of tests[b]	2	1

Standard Reproducibility by Direct Injection			
True value, ug/L	0.42	1.67	
Mean of standard run as unknown, ug/L	0.34	1.81	
Relative error from true value, % (accuracy)	- 19	+ 8	
Standard deviation about mean, % (precision)	± 6	± 15	
Number of tests	3	37	

a = 3000 concentration factor
b = Each test performed in triplicate

There were no field replicate data sets or replicate analyses data sets in which this compound was detected.

TABLE E-19. SIGNIFICANCE OF DDD AND β-ENDOSULFAN DATA BASE-NEUTRAL EXTRACTABLE HALOCARBON, GC/HALL DETECTOR[a] APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Extraction of Both Standards from Distilled Water		
Concentration, ug/L	0.33	3.33
Mean recovery, %	30	27
Standard deviation about mean, %	± 12	± 7
Number of tests[b]	2	1

Reproducibility of Both Standards by Direct Injection			
True value, ug/L	0.33	0.83	3.33
Mean of standard run as unknown, ug/L	0.22	0.73	3.44
Relative error from true value, % (accuracy)	- 33	- 12	+ 3
Standard deviation about mean, % (precision)	± 22	± 11	± 10
Number of tests	3	3	37

a = 3000 concentration factor
b = Each test performed in triplicate

There were no field replicate data sets or replicate analyses data sets in which these compounds were detected.

TABLE E-20. SIGNIFICANCE OF METHOXYCHLOR DATA
BASE-NEUTRAL EXTRACTABLE HALOCARBON, GC/HALL DETECTOR[a]
APPROXIMATE LOWER DETECTION LEVEL = 0.1 ug/L

Extraction of Standards from Distilled Water		
Concentration, ug/L	0.17	1.67
Mean recovery, %	62	56
Standard deviation about mean, %	± 12	± 19
Number of tests[b]	2	1

Standard Reproducibility by Direct Injection			
True value, ug/L	0.42	1.67	
Mean of standard run as unknown, ug/L	0.23	1.84	
Relative error from true value, % (accuracy)	- 45	+ 11	
Standard deviation about mean, % (precision)	± 51	± 42	
Number of tests	3	37	

a = 3000 concentration factor
b = Each test performed in triplicate

There were no field replicate data sets or replicate analyses data sets in which this compound was detected.

APPENDIX F

QUALITY ASSURANCE DATA FOR NON-HALOGENATED EXTRACTABLE HYDROCARBONS

The data presented here were generated as part of the quality assurance program discussed in Section 5. The analytical procedure employed for extractable halocarbons is detailed in Appendix D. Interpretation of project extractable halocarbon data presented in Section 7 was based, in part, on this quality assurance data.

TABLE F-1. EXTRACTION[a] OF STANDARDS FROM DISTILLED WATER, BASE-NEUTRAL EXTRACTABLE NON-HALOGENATED PRIORITY POLLUTANTS, GC/FLAME IONIZATION DETECTOR[b]

Compound	Approximate Lower Detection Level (ug/L)	Mean Recovery ± Standard Deviation, %						
		Concentration, 1.5 ug/L				Concentration, 10 ug/L		
		Test 1	Test 2	Test 3	Test 4	Test 1	Test 2	Test 3
Naphthalene	0.5	6±5	51±21	87±13	62±4	91±18	43±14	71±9
Acenaphthylene	0.5	19±2	51±34	104±15	53±1	65±24	32±23	76±10
Acenaphthene	1	21±2	49±27	80±7	71±15	79±1	47±13	69±10
Dimethyl phthalate	5	ND	23±10	136±163	ND	32±12	47±17	63±12
Fluorene	0.5	15±6		62±27	98±8	81±2	47±17	70±18
Diethyl phthalate	2	17±11	NFB	24±4	ND	48±21	25±6	23±323
Phenanthrene and Anthracene	1	19±2	57±23	81±5	102±4	79±2	58±14	82±8
Di-n-butyl phthalate	0.5	27±3	55±56	58±39	118±10	68±6	30±16	79±11
Fluoranthene	1	19±2	25±27	80±12	109±10	81±3	64±22	87±6
Pyrene	0.5	19±1	45±38	73±4	109±10	83±2	57±12	85±6
Butyl benzyl phthalate	2	7±7	NFB	33±20	96±28	51±15	NFB	31±8
bis(2-Ethylhexyl) phthalate and 1,2-Benzanthracene and Chrysene	1	20±3	NFB	47±18	54±5	71±10	NFB	51±5
Benzo(a)pyrene	5	ND	29±18	58±8	ND	60±3	18±7	46±8
Indeno(1,2:c,d)pyrene	10	ND	39±16	NFB	ND	73±20	21±6	53±10
1,2:5,6-Dibenzanthracene and 1,12-Benzoperylene	10	ND	43±15	NFB	ND	63±10	37±11	45±15

[a] Each test performed in triplicate

[b] 3000 Concentration factor

ND = Not detected

NFB = Not found after blank correction

TABLE F-2. STANDARD REPRODUCIBILITY BY DIRECT INJECTION, BASE-NEUTRAL EXTRACTABLE NON-HALOGENATED PRIORITY POLLUTANT COMPOUNDS, GC/FLAME IONIZATION DETECTOR

Compound	Approximate Lower Detection Level (ug/L)	True Value (ug/L)	Mean Concentration of Standard Run as Unknown n = 15 (ug/L)	Standard Deviation About Mean % (precision)	Relative Error From True Value % (accuracy)
Naphthalene	0.5	10	10.5	± 9.5	+ 5.0
Acenaphthylene	0.5	10	10.2	± 3.9	+ 2.0
Acenaphthene	1	10	10.2	± 4.9	+ 2.0
Fluorene	0.5	10	10.0[a]	± 5.0	0
Dimethyl phthalate	5	10	10.1[a]	± 8.9	+ 1.0
Diethyl phthalate	2	10	10.5	± 12	+ 5.0
Phenanthrene and Anthracene	1	20	20.4	± 4.4	+ 2.0
Di-n-butyl phthalate	0.5	10	10.4	± 5.8	+ 4.0
Fluoranthene	1	10	10.2	± 4.9	+ 2.0
Pyrene	0.5	10	10.1	± 5.0	+ 1.0
Butyl benzyl phthalate	2	10	10.6	± 5.7	+ 6.0
bis(2-Ethylhexyl) phthalate and 1,2-Benzanthracene and Chrysene	1	30	30.7	± 4.6	+ 2.3
3,4-Benzofluoranthene and 11,12-Benzofluoranthene	5	20	19.7	± 9.6	- 1.5
Benzo(a)pyrene	5	10	9.7	± 20	- 3.0
Indeno(1,2:C,D)pyrene	10	10	10.1	± 5.9	+ 1.0
1,2:5,6-Dibenzanthracene and 1,12-Benzoperylene	10	20	20.4	± 9.8	+ 2.0

[a] n = 11

TABLE F-3. STANDARD REPRODUCIBILITY BY DIRECT INJECTION, BASE-NEUTRAL EXTRACTABLE NON-HALOGENATED PRIORITY POLLUTANT COMPOUNDS, GC/FLAME IONIZATION DETECTOR

Compound	Approximate Lower Detection Level (ug/L)	True Value (ug/L)	Mean Concentration of Standard Run as Unknown n = 15 (ug/L)	Standard Deviation About Mean % (precision)	Relative Error From True Value % (accuracy)
Naphthalene	0.5	5	5.2	± 13	+ 4.0
Acenaphthylene	0.5	5	5.1	± 5.9	+ 2.0
Acenaphthene	1	5	5.1	± 12	+ 2.0
Dimethyl phthalate	5	10	10.6	± 21	+ 6.0
Fluorene	0.5				
Diethyl phthalate	2	5	5.6	± 18	+ 12
Phenanthrene and Anthracene	1	10	10.2	± 5.9	+ 2.0
Di-n-butyl phthalate	0.5	5	4.9	± 18	- 2.0
Fluoranthene	1	5	4.9	± 18	- 2.0
Pyrene	0.5	5	5.0	± 6.0	0
Butyl benzyl phthalate	2	5	5.1	± 5.9	+ 2.0
bis(2-Ethylhexyl) phthalate and 1,2-Benzanthracene and Chrysene	1	15	15	± 15	0
Benzo(a)pyrene	5	5	5.0	± 12	0
Indeno(1,2:C,D)pyrene	10	5	5.2	± 15	+ 4.0
1,2:5,6-Dibenzanthracene and 1,12-Benzoperylene	10	10	9.9	± 27	- 1.0

APPENDIX G

SOLVENT IMPURITIES AND HALOGENATED BY-PRODUCTS OF SOLVENT IMPURITIES

Burdick and Jackson distilled-in-glass methylene chloride contains a small amount of cyclohexene as a preservative. In the extraction laboratory, this compound reacts with any free chlorine present in project field samples to produce dichlorocyclohexane as a reaction product. Dichlorocyclohexane has the same retention time under the procedures described in Appendix D as bis(2-chloroethyl) ether and bis(2-chloroisopropyl) ether. It was necessary, then, to add thiosulfate to the sample bottle to quench free chlorine at the sample site.

This phenomenon was demonstrated in the laboratory when free chlorine spiked distilled water was extracted under the procedures described in Appendix D to produce 50 ug/L false positive reports of bis-chloro ethers.

Even with thiosulfate present in all sample bottles, a 0.04 to 0.3 ug/L false positive bis-chloro ether peak was present in all field samples chromatograms. The peak was also present in all solvent blank chromatograms. It was hypothesized that prior to extraction, a small amount of free chlorine resulted from methylene chloride degradation and reacted with the preservative to produce dichlorocyclohexane.

APPENDIX H

ATTEMPTED ANALYSIS OF BASE-NEUTRAL EXTRACTABLE ORGANO-NITROGEN COMPOUNDS

The compounds listed in Table H-1 are the nitrogen containing base-neutral extractable Priority Pollutants. Analysis for these compounds in project concentrated sample extracts was attempted. A Tracor model 702 nitrogen-phosphorous alkali flame ionization detector (sensitized to nitrogen) was interfaced to a Tracor model 560 gas chromatograph. The detector output was integrated and recorded by a Hewlett Packard 3380A programmable integrator. The GC/alkali detector lower levels of detection are also listed in Table H-1. A typical chromatogram resulting from direct injection of calibration standards at 6.66 ug/L is shown in Figure H-1. Extraction recoveries for calibration standards in distilled water were evaluated at three concentrations: 1.66 ug/L, 3.33 ug/L and 6.66 ug/L. These data are included in Table H-1. System blank evaluations (including extraction solvents) indicated occasional interference in areas of the chromatogram unrelated to Priority Pollutant retention times.

TABLE H-1. EXTRACTION RECOVERIES AND DETECTION LEVELS OF NITROGEN CONTAINING BASE-NEUTRAL COMPOUNDS

		Average Extraction Recovery		
Compound	Lower Detection[a] Level (ug/L)	1.66 ug/L Standard (%)	3.33 ug/L Standard (%)	6.66 ug/L Standard (%)
Nitrobenzene	4.0	32[b]	58[b]	--
2,6-Dinitrotoluene	0.4	61	80	87
2,4-Dinitrotoluene	0.1	50	73	87
N-nitrosodiphenylamine	0.4	72	84	91
Benzidine	4.0	61[b]	63	103
3,3'-Dichlorobenzidine	0.5	89	79	87

[a] With a GC/alkali flame ionization detector and 3,000 concentration factor.
[b] Only one determination.

Sample chromatograms produced under a thorough quality control program contained numerous peaks, some being presumptively identified as Priority Pollutants. See Figure H-2. GC/MS confirmation of the identifications, however, was not possible. For example, benzidine was frequently reported in project samples at concentrations ranging from 1.0 to 15 ug/L. For confirmation to occur by GC/MS, samples would have had to contain 20 to 50 ug/L of benzidine in order to elicit a sufficient scanning mode response. A comparable concentration was needed for scanning mode confirmation of the other nitrogen compounds. Problems were also involved in GC/MS confirmation by selected ion monitoring. According to the USEPA Protocol,[8] GC column conditioning with benzidine is necessary to chromatograph adequately the nitrogen-containing Priority Pollutants. Benzidine used in column conditioning resulted in an interference in confirmation attempts by selected ion monitoring. Other analytical methods likely available for characterization of this group of compounds were beyond the scope of the project.

An evaluation of the largest GC/alkali detector response presumptively identified as benzidine in a sample at 15 ug/L was attempted by GC/MS. A likely identification of the compound eliciting the response was squaline, a naturally occurring nitrogen compound ubiquitous in the environment. Because of the lack of GC/MS support for presumptive GC/alkali detector data, this analytical task was abandoned.

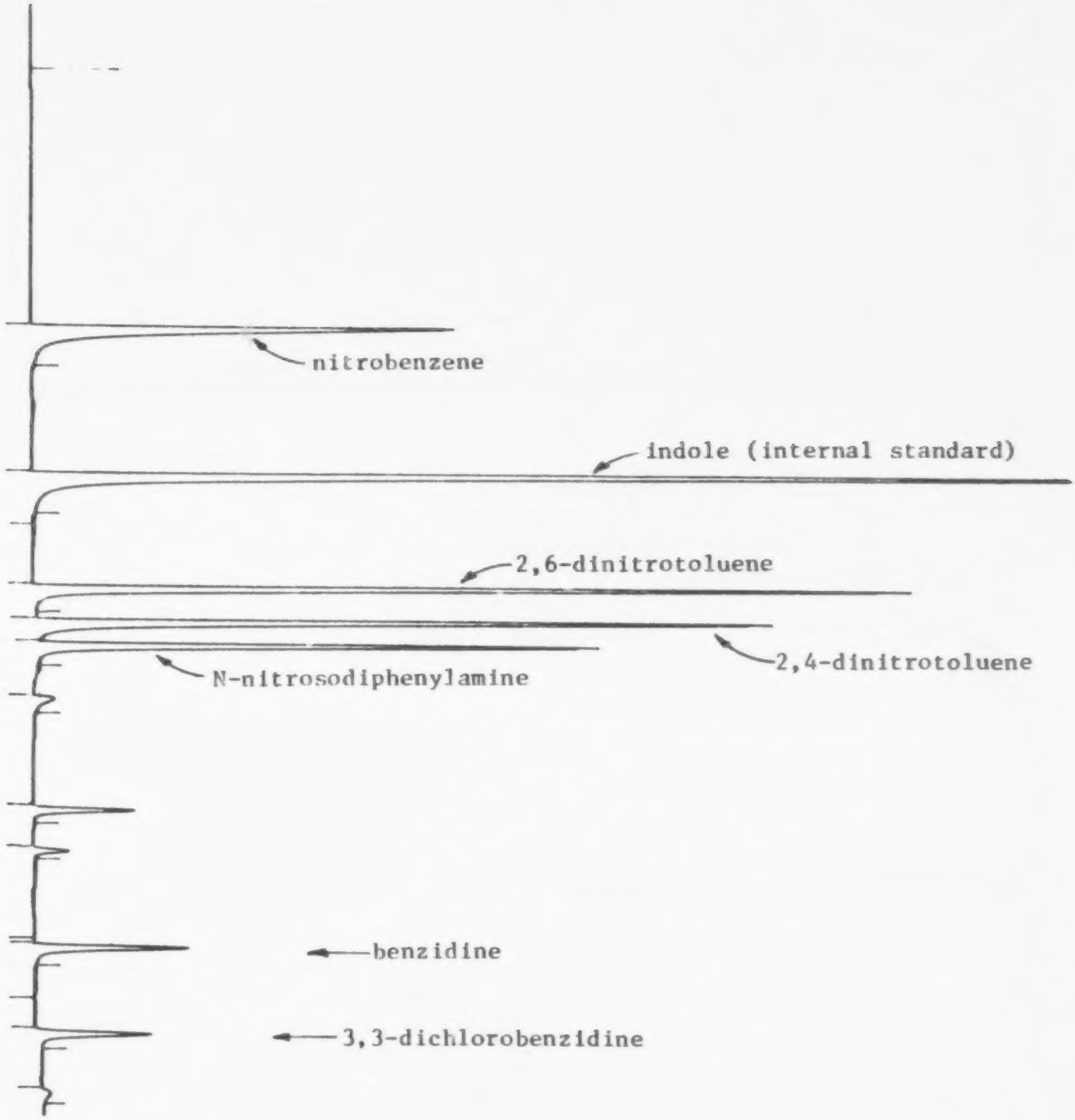
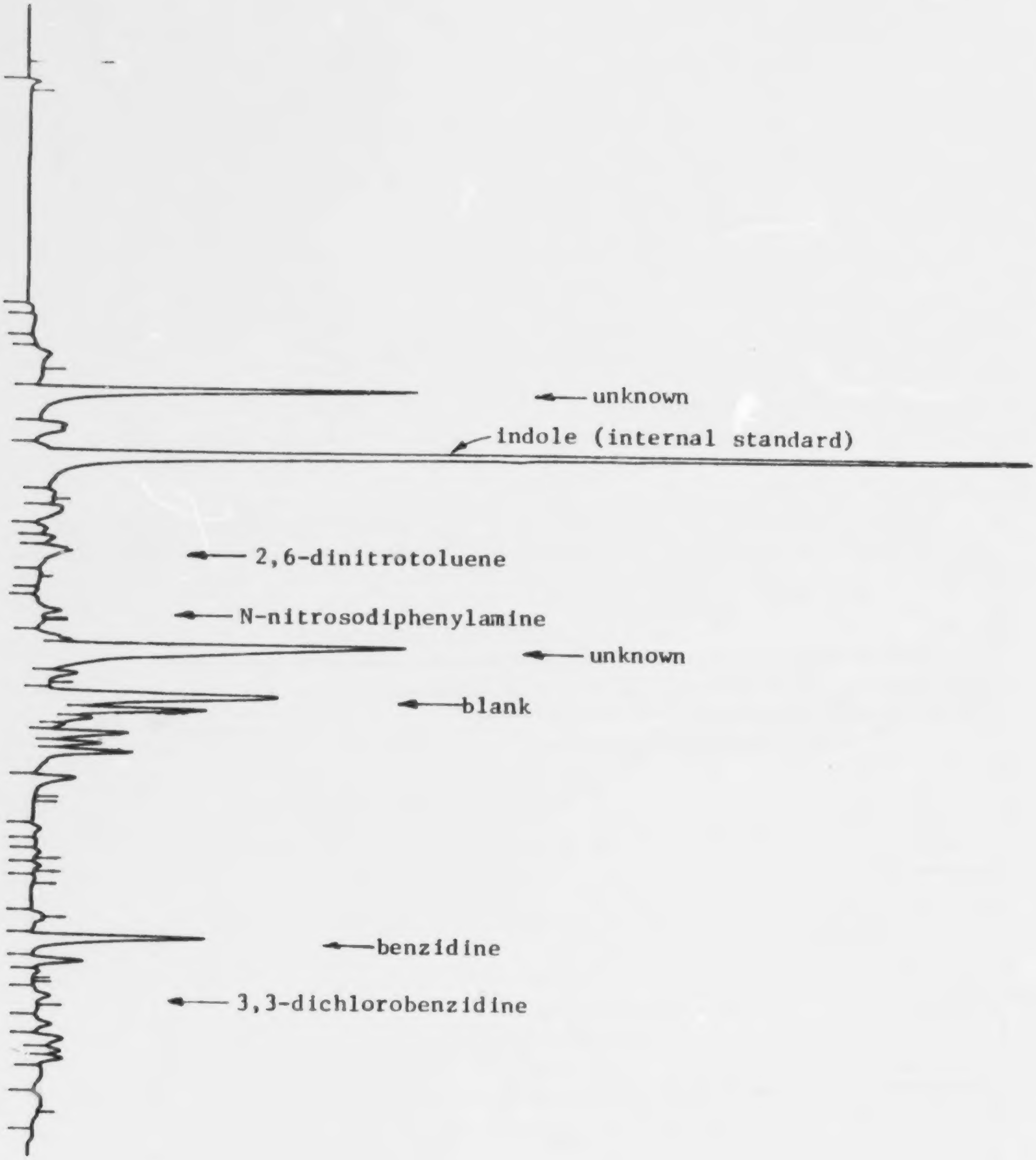


Figure H-1. Typical gas chromatogram of base-neutral extractable Priority Pollutants calibration standard using alkali flame ionization detector.



note: other peaks are unknowns

Figure H-2. Typical gas chromatogram of base-neutral extractable sample using alkali flame ionization detector.

APPENDIX I

MASS SPECTROMETRY EQUIPMENT AND ANALYTICAL PROCEDURES

The USEPA Protocol for analysis of Priority Pollutants by gas chromatography/mass spectrometry (GC/MS)[8] was closely followed by the GC/MS laboratory. Hewlett-Packard 5982A and 5985 combined gas chromatographs/mass spectrometers (GC/MS) and a Hewlett-Packard 5944A dedicated data system were used. The MS systems utilized jet separators for the GC effluents. The system performance was optimized daily for the analysis of 20 nanograms of decafluorotriphenylphosphine.

For analysis of purgeable halocarbons, a Tekmar model LSC-1 Liquid Sample Concentrator was interfaced to the GC/MS system. While a sample was purged, the GC oven was cooled to a subambient temperature of -50°C. Desorption from the Takmar was achieved in 8 minutes at 180°C onto the head of the GC column. At the end of the 8 minute period, the GC oven temperature had reached approximately -20°C. The temperature was then rapidly raised to 60°C and programmed according to protocol. MS scanning was started immediately.

APPENDIX J

ORGANIC SAMPLING PROCEDURES

INSTANTANEOUS LEVEL PURGEABLE SAMPLING PROCEDURE

The 40 mL bottles for the sampling of purgeable compounds contain powdered sodium thiosulfate. This substance must not be lost during sampling. Therefore, it is extremely important that the sample water gently flow into the bottle such that the bottle will be filled with little or no spillover.

If the water to be sampled is not tapped, use a beaker to introduce the sample water to the 40 mL bottle. This beaker should have been thoroughly washed, rinsed with distilled water and air dried. At the sample site, rinse the beaker several times with the sample water prior to collection.

Remove the cap from the bottle to be filled, being careful not to spill any of the thiosulfate out of the bottle. Avoid fingering the lip of the bottle. Fill the bottle carefully with gently running water from the tap or from the beaker until a convex meniscus forms above the lip of the bottle. Carefully place the cap on the bottle and screw it securely in place. The displaced meniscus will run down the sides of the bottle. Invert the bottle several times. There should be no air space in the bottle larger than this letter "O". Dry the bottle off, label it properly and secure it with transparent tape. Refrigerate it in the dark until sample shipping time.

TERMINAL LEVEL PURGEABLE SAMPLING PROCEDURE

Two bottles are required for this procedure. A 270 mL bottle is used for sample storage during which time available trihalomethane precursor will react with chlorine to form trihalomethanes. The sample will be collected in this bottle. A 40 mL bottle contains powdered thiosulfate to stop the trihalomethane reaction and is used to ship the sample for analysis. The 270 mL bottle will be shipped back empty to the laboratory for cleaning.

The 270 mL bottles contain a buffer with a pH at or near the utility's finished water pH. This buffer must not be lost during sampling. Therefore, it is extremely important that the sample water gently flow into the bottle such that the bottle will be filled with little or no spillover.

To ensure the reaction reaching its formation potential, the sample is usually chlorinated. Therefore, prior to sample collection, a stock chlorine solution must be prepared.

A chlorine stock solution bottle and a 10 mL pipette should be readied prior to preparing the solution. Wash them and thoroughly rinse them with distilled water. Allow them to dry. Weigh out 800 mg of reagent grade $Ca(OCl)_2$ and add it to 1.0 liter of distilled water. This should give a stock strength of approximately 400 mg/L free chlorine. This solution should be stored in a dark or aluminum foil wrapped glass stoppered bottle in a refrigerator that is free of organic chemicals, glues, solvents, etc. If is has been stored for longer than a week prior to use, discard it and prepare a new solution.

After chlorinating this sample, storing it for the designated time and transferring to the 40 mL bottle containing thiosulfate, it will be necessary to determine the free chlorine residual of the sample remaining in the 270 mL bottle. The buffer in that bottle, however, may interfere with the chlorine measurement. It will be necessary, therefore, to prepare an acid solution so that the pH can be adjusted prior to making the chlorine measurement. For this purpose dilute one part reagent grade H_2SO_4 into 40 parts distilled water.

Immediately before sampling, pipette 10 mL of the stock chlorine solution into the 270 mL bottle, being careful not to lose any of the buffer. Cap the bottle. Go to the sample location.

Remove the cap from the 270 mL bottle being filled, being careful not to spill any of the chlorine and buffer solutions in the bottle. Avoid fingering the lip of the bottle. Fill the bottle carefully with gently running water from the tap or from the beaker until a convex meniscus forms above the lip of the bottle. Carefully place the cap on the bottle and screw it securely in place. The displaced liquid will run down the sides of the bottle. Gently invert the bottle several times to mix the sample and buffer and chlorine solutions. There should be no airspace in the bottle larger than this letter "O." Dry the bottle off, label it properly, and secure it with transparent tape. Store it in the dark at a temperature approximating that of the finished water until it is time to transfer it to the 40 mL bottle.

At the specified transfer time, remove the cap from the 40 mL bottle to be filled, being careful not to spill any of the thiosulfate. Avoid fingering the lip of the bottle. Remove the cap from the 270 mL bottle. Pour the sample carefully from the 270 mL storage bottle into the 40 mL bottle until a convex meniscus forms above the lip of the bottle. Carefully place the cap on the bottle and screw it securely in place. The displaced liquid will run down the sides of the bottle. Invert the bottle gently several times and check for air bubbles. Dry the bottle off, label it properly, and secure the label with transparent tape. Refrigerate the 40 mL bottle in the dark until sample shipping time.

There should be approximately 230 mL of sample remaining in the 270 mL bottle. Use this 230 mL to determine the remaining free chlorine residual by whatever means you normally use for determination of free chlorine residual. Measure out the volume required. Add the acid solution drop by drop until the solution is very near pH 7. Then continue with the routine procedure for the utility's free chlorine residual determination. Record this residual.

EXTRACTABLE SAMPLING PROCEDURE

The gallon bottles for the sampling of extractable compounds will arrive at the utility containing granular thiosulfate.

Remove the cap from the bottle. Fill the gallon bottle carefully with gently running water from a tap or from a beaker. Fill the bottle to very near the top, being careful not to lose any of the thiosulfate. This bottle does not have to be filled airspace free. Fill it to very near the top. Cap the bottle. If the outside of the bottle was wetted, dry it off. Label it properly and secure it with transparent tape. Refrigerate it in the dark until sample shipping time.

APPENDIX K

PROCEDURE AND MEDIUM FORMULA FOR A MEMBRANE FILTER - STANDARD PLATE COUNT

The laboratory apparatus needed is basically identical to that required for the total coliform procedure as written under 909A, pages 928 to 931, a through k, Standard Methods for the Examination of Water and Wastewater, 14th Edition, 1976 (SM). The exception is that the medium is to be used as an agar only; therefore, the description of absorbent pads is not applicable.

Medium and Preparation	
Peptone	2 grams
Gelatin	2.5 grams
Glycerol	1.0 mL
Agar	1.5 grams
Distilled Water	100. mL

Adjust to pH 7.1 with NaOH (N) and autoclave for five minutes at 121°C. Sterile medium is dispensed in 4-6 mL volumes into 60 by 15 mm petri dishes. If possible medium should be prepared daily; however, prepared plates of sterile medium can be stored at 4°C for one week.

The procedure for sample filtration is identical to sample filtration for determination of total and fecal coliforms by the membrane filter technique. The same precautions should be taken when rolling the membrane onto the agar surface to avoid air bubble entrapment.

The selection of sample size should be determined as if the standard pour plate procedure were to be utilized, particularly if raw water is examined. When finished, potable water is examined, it is suggested that 100, 50, 25, 10 or 1-mL volumes be filtered.

The exact volume must instantly be determined by the analyst. It is recommended that three different volumes for each sample be routinely filtered due to normal variations in total bacterial density regardless of the source of the sample.

Culture plates are incubated for 48 hours in an inverted position in an incubator which maintains a 35° ± 0.5 °C temperature. All colonies regardless of size and color are counted.

Report the total bacterial density in terms of total bacteria/1 mL.

Compute the count by the following equation:

$$\text{Total bacteria colonies/1 mL} = \frac{\text{total colonies}}{\text{mL of sample filtered}} = \text{density/1 mL}$$

Membrane filters showing confluent growth, over 200 colonies, or colonies which cannot be individually discerned should not be used for calculating total bacterial density.

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* As of June, 1979